

<https://helda.helsinki.fi>

Collaborative science education at the University of Helsinki:
ChemistryLab Gadolin : a science lab as an inspiring
environment for learning, development and research since 2008

Aksela, Maija

University of Helsinki

2018-09-19

Aksela , M , Pernaa , J , Blomgren , P & Rautiainen , I 2018 , Collaborative science education at the University of Helsinki: ChemistryLab Gadolin : a science lab as an inspiring environment for learning, development and research since 2008 . University of Helsinki , Helsinki .

<http://hdl.handle.net/10138/306421>

unspecified
publishedVersion

Downloaded from Helda, University of Helsinki institutional repository.

This is an electronic reprint of the original article.

This reprint may differ from the original in pagination and typographic detail.

Please cite the original version.

COLLABORATIVE SCIENCE EDUCATION AT THE UNIVERSITY OF HELSINKI

**CHEMISTRYLAB GADOLIN – A SCIENCE LAB AS AN
INSPIRING ENVIRONMENT FOR LEARNING,
DEVELOPMENT AND RESEARCH SINCE 2008**

**Maija Aksela, Johannes Pernaa,
Pipsa Blomgren & Iisa Rautiainen**

Pictures on the cover:

Elisa Lautala

Sonja Martikainen

Veikko Somerpuro

Sakari Tolppanen

Layout: Johannes Pernaa

ISBN 978-951-51-4505-5 (pkb.)

ISBN 978-951-51-4506-2 (PDF)

Unigrafia Oy
Helsinki 2018

TABLE OF CONTENTS

Foreword	5
1 ChemistryLab Gadolin as a Pioneer and a Collaborative Impactor	10
1.1 Background Information.....	10
1.2 A Collaborative Operating Model.....	13
1.3 Focus Areas of the Operations	15
1.4 New Solutions and Pedagogical Innovations with Design-Based Research	17
2 ChemistryLab Gadolin as a Part of National and International Collaboration	19
2.1 Background Information.....	20
2.2 National Collaboration with the LUMA Centre Finland Network.....	20
2.3 International Collaborative Projects.....	22
3 ChemistryLab Gadolin as an Inspiring Learning Environment for Children and Youth	24
3.1 Aims and Significance of the Operations.....	24
3.2 Target Groups	25
3.3 Forms of Operation.....	27
3.3.1 General Information.....	27
3.3.2 Inquiry-Based Learning	32
3.3.3 Molecular Modelling and Other Kinds of Digital Learning	34
3.3.4 Exploring the Research of Chemistry and Researchers.....	35
3.3.5 Science Clubs, Science Camps and Science Birthdays.....	36
3.3.6 Other Events of Science Education.....	38
4 ChemistryLab Gadolin in Teacher Education and in its Research	40
4.1 General Information	41
4.2 Collaborative Models in Teacher Education.....	43
4.3 Collaborative Models in Teachers' In-Service Education	45
4.4 Operations as a Research and Development Centre	47
4.4.1 Research on ChemistryLab Gadolin as a Learning Environment	49
4.4.2 Research on Phenomena and Approaches	51
4.4.3 Design-Based Research as a Tool: Development of New Solutions and Pedagogical Innovations	52
5 ChemistryLab Gadolin's Models for Corporate Collaboration.....	53
5.1 General Information	53
5.2 Models for Corporate Collaboration	53
Afterword	58
References	59
Appendices.....	62
Appendix 1. The Collaborative Gadolin Team	62
Appendix 2. Cooperation Partners and Sponsors	68

FOREWORD

The science lab ChemistryLab Gadolin has been named after an internationally famous Finnish Professor in Chemistry, Johan Gadolin (1760-1852), the father of Finnish chemical research. He emphasized the fact that inquiry has a central significance in the teaching of chemistry, which is why it also forms the basis for the operations of Gadolin. Johan Gadolin was one of pioneers of the promotion of inquiry also internationally. Professor Gadolin had a strong effect on the Finnish Industry as a member of the Finnish Economic Society. Close collaboration with the Industry as well as developing new, inspiring solutions and pedagogical innovations together into science education in chemistry from early childhood education to universities, is also an important aim in the operations of Gadolin.

The bright future of Chemistry and Finland is in the hands of skillful and inspired makers of the future – the children and youth – and in their competent teachers and instructors. Science education in chemistry that is both collaborative and is based on most novel research has a central role in this.

The main aim of science education operations of chemistry is to promote the knowledge and skills in science from early childhood education to universities. This anniversary book introduces ChemistryLab Gadolin, its collaborative science education in chemistry and teacher education and its research from early childhood education to universities. The science lab¹ is located at the University of Helsinki, in the Faculty of Science in the Department of Chemistry, near the Unit of Chemistry Teacher Education. The anniversary book deepens the descriptions of science education in chemistry of the 15th Anniversary Book of the Science Education Centre (Aksela, Oikkonen, & Halonen, 2018) that was published in the beginning of 2018. The book has been comprised through annual reports and research and theses that have been connected to the operations.

ChemistryLab Gadolin that is celebrating its 10th anniversary in 2018 is a **pioneer** in the science lab network of Finnish universities: it was established as the first science lab of 14 science labs that operate under the national LUMA Centre Finland network². The activities of Gadolin are a good example of a collaborative operating model, where the university researchers, teacher educators and partners outside the university operate together in order to strengthen children and youths' know-how of chemistry and their interest towards chemistry. In the operating model, close cooperation with the Industry is especially unique and it has enabled new, relevant operating models for inspiring makers of the future towards studying chemistry (see

¹ helsinki.fi/en/science-education/for-teachers/group-visits-to-science-labs/chemistrylab-gadolin

² luma.fi/en

Chapter 5). As recognition of its operations, the science lab ChemistryLab Gadolin has been awarded with the **international Global Best Awards** recognition in 2014.

The activities of ChemistryLab Gadolin aim at an engaging and a meaningful science education in chemistry that produces **joy of insight and success** through new and inspiring openings as well as solutions. It aims at supporting the planning of the core curriculum for chemistry and its implementation in different school levels. In the past 10 years, **over 50 000 children, youth, teachers and other visitors** have become acquainted with the popular operations, and the received feedback has been encouraging. It is also **an internationally intriguing operating model**: up until now, a couple thousand visitors have become acquainted with it. In 2017, around 200 visitors visited the Gadolin from countries such as Australia, China, France, Germany, Indonesia, Lithuania, Morocco, Singapore, Slovenia, South-Africa, South-Korea and Tunisia.



Figure 1. The science lab ChemistryLab Gadolin's operating model interests both nationally as well as internationally – for example the **Finnish Minister of Education** Sanni Grahn-Laasonen and the **South-African Minister of Education** Angela Motshekga have gotten to know activities that inspire children and youth. During the academic year, international guests visit the science lab on a weekly basis.

ChemistryLab Gadolin itself aims at promoting the objectives set by the Ministry of Education: Finland as one of the leading countries in science education in the world by the year 2020 (Ministry of Education and Culture, [2014](#)). Science education has a crucial role in society's future (Ahonen, [2017](#); Aksela, [2012](#)). Children and youth interested in science strengthen Finland's bright future, and this is a central part of the societal role of universities (Aksela, [2017b](#)). At the University of Helsinki, systematic and collaborative science education in chemistry (a part of the national LUMA Centre Finland) has been carried out since 2003 (Aksela et al., [2018](#)). ChemistryLab Gadolin promotes science education in chemistry and is a part of the operations of the Science Education Centre (a part of LUMA Centre Finland; see [Chapter 1](#) for further information) at the University of Helsinki and it carries out the agenda that has been approved by the executive board.

In science education in chemistry, global impacting is being aimed at according to the University of Helsinki's science education operations that are based on strategy and according to the alignments of the national LUMA Centre Finland. The operations of the ChemistryLab Gadolin act as a signpost and as a creator of new solutions and pedagogical innovations and it as well aims at supporting the planning and implementation of new and future **curricula** in chemistry. An important aim of Gadolin's science education in the strategic period of 2017–2020 is especially to develop new and relevant openings in the teaching of **everyday chemistry, sustainable chemistry and development as well as modern technology**, and in teacher education³ (see [Chapter 1](#) for further information).

One of the aims of the operations is to make chemical research, researchers and different chemical professions familiar to the children and youth as well as teachers. New innovations in chemical research are aimed at being brought forward in a meaningful way in the operations of the Gadolin and to promote the relationship between researchers – good role models for children and youth – and teachers. The science education operations of the ChemistryLab Gadolin are in close connection with the researchers in the Department of Chemistry⁴ at the University of Helsinki and teachers as well as with the specialists from the Industry. In the near future, especially the presence of young researchers as role models or so-called messengers of chemistry is going to be emphasized even more in the operations. For example, new forms of collaboration have been developed with the upper secondary schools in order to support meaningful studying for upper secondary school students (see [Chapter 3](#)).

Figure 2. Finnish know-how of chemistry and its important significance are being brought forward in different ways. ChemistryLab Gadolin is in close cooperation with the research of chemistry. Researchers from both the university and the Industry act as **role models** for children and youth, and they support teachers in their important work. The Director of the Department of Chemistry, Professor **Heikki Tenhu** can be seen in the picture as he is inspiring the participants – makers of the future - of the science club *Chemistry and Art* towards studying chemistry.



³ LUMAT Special Issue: Promoting innovative and collaborative chemistry education through evidence-based chemistry teacher education. *LUMAT*, 1(3) (2016). umat.fi/index.php/lumat-b/issue/view/2

⁴ Department of Chemistry, University of Helsinki. helsinki.fi/kemia

In the science education of ChemistryLab Gadolin, both the **future teachers and teachers teaching on different school levels** have the possibility of getting acquainted with new solutions and pedagogical innovations in the teaching of chemistry and through these they are able to inspire the makers of the future towards studying chemistry. Collaboration especially with the personnel of the Unit of Chemistry Teacher Education⁵ that operates in the Department of Chemistry within the Faculty of Science at the University of Helsinki and with researchers and students is close (see [Chapter 4](#)). Through collaboration, the most novel information and networks of national and international research on the teaching of chemistry, are at the hands of science education operations of ChemistryLab Gadolin. The strong relationship between Chemistry Teacher Education and the operations of Gadolin have received international recognition, and it has been used elsewhere as well. The significance of teacher education organized by Gadolin is vast, when we take into consideration the long-term effects of a teacher's work:

“Every teacher has an effect for around 100 years: first during the time that they teach and then through their own students”

Finnish LUMA science education is strongly **based on research**. ChemistryLab Gadolin acts as a central research and development environment for science education and teacher education in chemistry (see [Chapter 4](#)). It brings new research information in versatile ways into teaching from early childhood education to universities and comes up with new openings on the basis of research. The research method used is mainly collaborative and engaging design-based research (see [Chapter 1](#) and [Chapter 4.4.3](#)). This research involves researchers in chemistry and its teaching, specialists in Industry, teachers teaching on different school levels as well as future teachers. The used model for design-based research is also a new kind of an educational model for teachers, where all the participants can learn from each other. The specialists also learn from teachers – from the specialists of pedagogical know-how. Numerous theses and research with their academic articles are produced in order to strengthen scientific know-how. A doctoral thesis (Ikävalko, [2017](#)) and a Master's Thesis (Blomgren, [2018](#)) have been comprised especially concerning the relevancy of the operating model of ChemistryLab Gadolin ([Chapter 3.1](#)). The aim is to get all the new openings widely into use in different forums – through textbooks for teaching in different school levels and in learning environments as well as in teachers' pre-service and in-service education.

The science education operations of chemistry are connected to the development of university level chemistry as well as research (see [Chapter 4](#)). In the teacher education of pre-service and in-service chemistry teachers, the different forms of science education (e.g. instructing in a science lab, clubs, science adventures, camps, science birthdays and collaboration on the upper secondary level) act as inspiring

⁵ The Unit of Chemistry Teacher Education, University of Helsinki. blogs.helsinki.fi/kem-ope/en

ways of implementation for education. A good example of new openings of science education that are connected to basic education of chemistry at the university is the course *Chemistry as a Science*, which is partly carried out in cooperation with the course *Chemistry of health and well-being* that is aimed at students on the upper secondary level. Upper secondary school students, pre-service teachers and young researchers work together during the course and learn from one another. Teachers are educated on new solutions and pedagogical innovations through virtual and interactive MOOCs that are also the subjects of development (see [Chapter 4](#)). At the same time, they act as education and interaction forums for pre-service teachers, in-service teachers teaching on different school levels.

On this anniversary year, we would warmly like to express our thanks for outstanding collaboration with the management of the University of Helsinki, the Faculty of Science and the Department of Chemistry as well as other administrations that have promoted and supported the operations and development of ChemistryLab Gadolin along the years.

Many thanks to the active participants of ChemistryLab Gadolin's steering groups (see [Appendix 1](#)), important sponsors of the operations (see [Appendix 2](#)), coordinators (the "hearts" of the operations) (see [Appendix 1](#)), numerous skillful instructors (see [Appendix 1](#)), active researchers and specialists in chemistry, collaborative team at the Unit of Chemistry Teacher Education and students, active teachers in different school levels, the science education team and successful national and international partners. According to our motto **together we are more!**

Here, we would like to thank also those that have been awarded with the Gadolin Ambassador recognitions, **Timo Leppä, Ilkka Pollari, Mikko Ritala, Markku Räsänen, Heikki Tenhu and Hannu Vornamo** for exemplary collaboration with forming and promoting the operations of ChemistryLab Gadolin, and supporting the Director of ChemistryLab Gadolin, Professor Maija Aksela.

ChemistryLab Gadolin operates mainly with the help of outside funding and in order to be able to develop further, extra resources are needed. We gladly accept donations to the Science Education Fund⁶ both from Finland and abroad in order to enable new openings and collaboration.

Together towards a bright future for chemistry!

In Helsinki on the 10th Anniversary of ChemistryLab Gadolin, September 19th, 2018.

Professor Maija Aksela
Director

University Lecturer Johannes Pernaa
Vice Director

Pipsa Blomgren
Coordinator

Iisa Rautiainen
Vice Coordinator

⁶ helsinki.fi/en/science-education/centre/donate-to-the-science-education-fund

1 CHEMISTRYLAB GADOLIN AS A PIONEER AND A COLLABORATIVE IMPACTOR

In this chapter, the collaborative operating model and the history of ChemistryLab Gadolin that is celebrating its 10th Anniversary in 2018, is going to be presented. The science lab is a **pioneer in the network of science labs** in the LUMA operations of Finnish universities: it was established as a first science lab of the 14 science labs of the national LUMA Centre Finland⁷.



Figure 3. The science lab ChemistryLab Gadolin in the Department of Chemistry at the University of Helsinki. This modern laboratory with its research equipment makes it possible to get to know the nature of chemistry as a science and to explore fascinating possibilities, and it also encourages children and youth towards studying chemistry.

1.1 Background Information

The present state of the teaching of chemistry, the possibilities and challenges on different levels have been charted once every ten years since 1998, directed by professor Maija Aksela (Aksela & Juvonen, [1999](#); Aksela & Karjalainen, [2008](#); Aksela, Pernaa, & Hopea-Manner, published in 2019). Based on surveys, different kinds of forms of support have been comprised into the teaching of chemistry. In a research carried out in 1998, a grand need for supporting the lifelong learning of chemistry teachers was discovered, mainly concerning meaningful inquiry, information and

⁷ helsinki.fi/en/science-education/for-teachers/group-visits-to-science-labs

communications technology and school corporate collaboration as well as the need for increasing interaction between universities, schools and the industry.

In order to attend to the challenges discovered in the research, a centre for the teaching of Chemistry, Kemma that promotes science education in chemistry was established alongside the operations of the national LUMA Centre and the **Unit of Chemistry Teacher Education** in the Department of Chemistry at the University of Helsinki in 2004. The national LUMA Centre (the predecessor of LUMA Centre Finland) at the University of Helsinki was established as an umbrella organization for the collaboration between schools, universities and the Industry⁸. The aim was that in successful interaction, all the participants can learn from one another.

To strengthen meaningful inquiry-based teaching of chemistry in schools and to inspire children and youth towards studying chemistry, the director of the Department from that time, Professor **Markku Räsänen** and Professor **Maija Aksela** from the Unit of Chemistry Teacher Education started new science lab operations on Aksela's proposal, the preparations for the incoming ChemistryLab Gadolin. Since the beginning, the aim was to build a modern learning environment that supports the teaching of chemistry in schools and as well teacher training in collaboration with different partners – mainly those in the field of chemistry. The aim of the upcoming operations was also to strengthen the entire school collaboration of the Department of Chemistry. The Department had had a long and successful tradition of school collaboration from the 1980's onwards between research laboratories and numerous schools. **Currently there are 13 companies collaborating with Gadolin, in addition to the Chemical Industry Federation of Finland** (see [Appendix 2](#)).

Kemira Oyj's decision to give up the popular **Chemistry Lab** operations alongside Kemira's Research Centre and to start collaboration with us brought a significant push towards promoting and preparing for the science lab. Kemira Oyj's popular Chemistry Lab had been operating since the 1990's in a Research Centre in Suomenoja, Espoo. It was a part of Kemira's corporate communications and its main aim was to support the teaching of chemistry, to familiarize schools and children about the Chemical Industry and to build a company image. At its best, the operations reached 1500 students and chemistry teachers each year (compare: today ChemistryLab Gadolin reaches around 4000 students and chemistry teachers each year). The Chemistry Lab had been offering primary school and upper secondary school teachers and their students a possibility for working and learning in an authentic laboratory environment of the company. The visiting teacher had chosen the appropriate work for their class from a collection of laboratory work. The work was completed under the instruction of the visiting student group's teacher, while Kemira's contact person was mostly in the background (compare: In ChemistryLab Gadolin, visiting students are instructed by pre-service chemistry teachers or chemists that have received education for the job). In addition, visits included a presentation of Kemira Oyj and a tour of the Research Centre.

⁸ luma.fi/en/centre

Through collaboration, Kemira Oyj became one of the main sponsors of ChemistryLab Gadolin and representatives of the company are members of its steering group.

The continuation of the collaboration at the Department of Chemistry was assisted by the fact that the “mother” of ChemistryLab Gadolin, Professor **Maija Aksela**, was well acquainted with the meritorious operations of the Chemistry Lab. She had worked in collaboration with Kemira Oyj’s Chemistry Lab with almost the entire time that it had been operating and had developed most of the used inquiry-based experiments and had trained teachers alongside her own work. As the collaboration continued, the inquiry-based experiments that were developed in the Department of Chemistry and the resources of the Chemistry Lab (equipment and chemicals) were transferred into use in ChemistryLab Gadolin.

From the industry, the board of Kemira Oyj gave significant support in building ChemistryLab Gadolin, especially the Chief Communication Officer from that time **Timo Leppä** (later the Director General of the Chemical Industry Federation of Finland) and the Director of the Research Centre, **Ilkka Pollari** from Kemira’s Research Centre as well as the General Director of the Chemical Industry Federation of Finland, **Hannu Vornamo**.

Supported by their precious advice, Maija Aksela started to form the collaborative operating model in order to promote ChemistryLab Gadolin and to form the 3-year collaboration contracts together with companies and partners (see Appendix 1 and 2) as well as started to put together the steering group (see Appendix 1). Collaborative models and resources for them were agreed upon with each and every partner and collaboration contracts were signed. In addition to the financial resources, an important form of collaboration is the company’s specialists taking part in developing the contents of the operations. In the beginning, collaboration was carried out as a pilot project that lasted for three years, after that it has been continued with renewing the contracts every three years. **Without the significant support and resources offered by the industry, the operations of ChemistryLab Gadolin would not have reached the extent that is described in Chapter 3.** Different forms of collaboration with the industry are described in more detail in Chapter 5.

The science lab ChemistryLab Gadolin that operates as a part of the national LUMA Centre at the University of Helsinki was opened in **a festive environment in September 19th, 2008** at the Department of Chemistry alongside a *Chemistry Today* educational event. The Director General of Kemira Oyj’s Research Centre, **Ilkka Pollari**, who has been awarded with the Gadolin ambassador recognition in 2018 for significant collaboration, held an inspiring opening speech⁹

Today, ChemistryLab Gadolin is administratively a part of the operations of the Science Education Centre (earlier known as the University of Helsinki’s LUMA Centre) at the University of Helsinki. Collaboration strengthens the visibility of the operations of ChemistryLab Gadolin nationally and internationally, and also enables

⁹ The opening ceremony of ChemistryLab Gadolin 19.9.2008: youtube.com/watch?v=G2cRyQJ7U7I

close and interdisciplinary collaboration. The Science Education Centre represents the University of Helsinki in the national LUMA Centre Finland network¹⁰, the administration of which the University of Helsinki has been looking after ever since its establishment (since 2013). LUMA Centre Finland has a national purpose, and the Science Education Centre participates in this as a collaborative compactor.

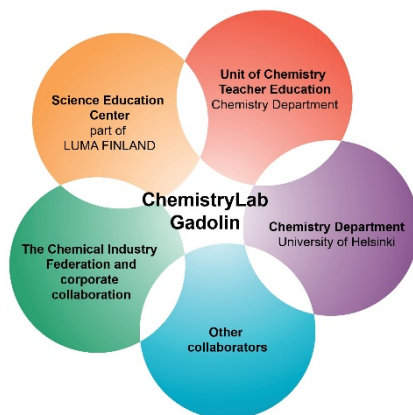


Figure 4. An artist, the popular "sound laborant" Miro Mantere performed in the opening festivities of ChemistryLab Gadolin in 2008 and he will also be performing in its 10th Anniversary in 2018. (Picture: Sakari Tolppanen)

1.2 A Collaborative Operating Model

Science education of ChemistryLab Gadolin from early childhood education to universities is promoted collaboratively with the university, Industry and other cooperation partners (e.g. the Finnish National Agency for Education, teacher organizations and schools of different levels).

Figure 5. In the collaborative operating model of ChemistryLab Gadolin, good interaction with different cooperation partners is crucial. There are 13 participating companies working with Gadolin.



¹⁰ luma.fi/en

The operations of ChemistryLab Gadolin are carried out according to the annual plan of action that is approved by the executive board of the Science Education Centre (a part of the LUMA Centre Finland network). The Centre's **executive board** is directed by the Dean of the Faculty of Science, and in the executive board¹¹, there are representatives of all the faculties working with the Centre. In the Centre's steering group, there are numerous partners alongside the representatives from the university such as from the Finnish National Agency for Education and from the Industry. The current administration model of the Science Education Centre has been described in [Figure 6](#).

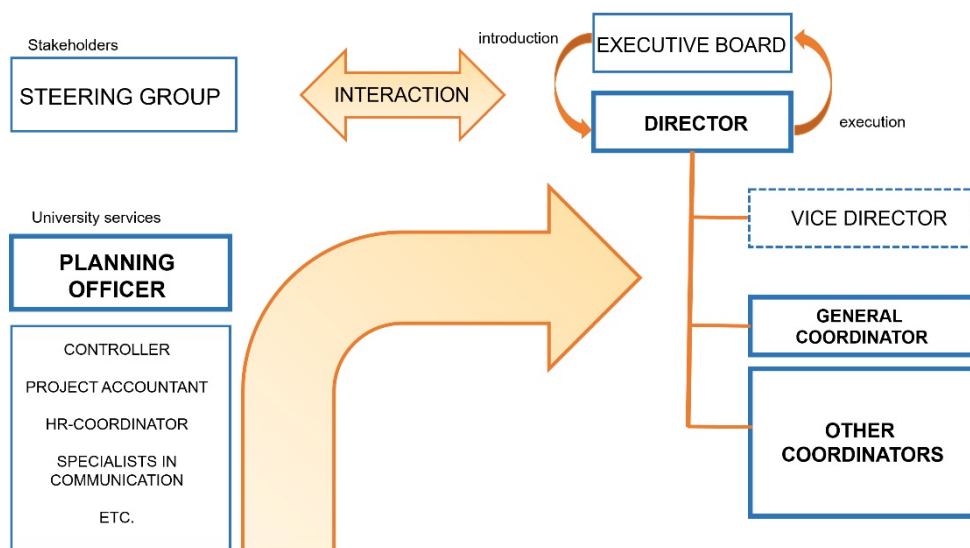


Figure 6. ChemistryLab Gadolin is a part of the administration of the University of Helsinki's Science Education Centre and its science education operations. **The executive group consists of administration from the different faculties from the University of Helsinki.** ChemistryLab Gadolin's coordinator and the vice coordinator carry out the Centre's plan of action in collaboration with science education coordinators of different fields under the guidance of the Centre's Director. The Director of the Science Education Centre acts as the director of ChemistryLab Gadolin and for the time being also as the director of LUMA Centre Finland (has been operating since it was established in 2013).

The resources for the operations of ChemistryLab Gadolin mainly consist of complementary funding from cooperation partners (see [Appendix 2](#)) and in addition support is received from the Science Education Centre (a part of LUMA Centre Finland) and from the Department of Chemistry at the Faculty of Science. In addition, the cooperation partners support the operations with equipment and materials as well as with their expertise. The forms of collaboration have been defined with each and every cooperation partner with a collaboration contract that is compiled every three years.

¹¹ helsinki.fi/en/science-education/centre/leadership-and-decision-making

The so called **collaborative Gadolin team** participates in planning and carrying out the operations of ChemistryLab Gadolin: the director, the vice director, the steering group/development work group, the coordinator, the vice coordinator and instructors (see the names in Appendices 1 and 2). In addition, doctoral students of the Unit of Chemistry Teacher Education take part in its several development and research projects.

The **Coordinator** and **Vice Coordinator** of science education at ChemistryLab Gadolin act as specialists of their own field and as instructors for carrying out the operations, under the instruction of ChemistryLab Gadolin's director and vice director (see names in [Appendix 1](#)). They are usually students completing their Master's Degree at the Unit of Chemistry Teacher Education or postgraduate students, who usually write their theses based on the operations of Gadolin. Hands-on study visits are instructed either by researchers in chemistry or students, who are studying to be teachers (see the names in [Appendix 1](#)), the instructors have received education concerning the job. The instructors of Gadolin have regular and collaborative meetings that are arranged by the coordinator. In these meetings, the participants go through the operations in practice and both evaluate and develop them.

The **steering group** of ChemistryLab Gadolin has operated actively since its early years (see [Appendix 1](#)). Both, representatives from the university and representatives from cooperation partners outside the university take part in the steering group. The steering group has participated in the planning and evaluation of the operations. Since Fall 2018, it will carry on with the name **development group** (such a change is necessary as there is an overlap with the name steering group), representatives from the industry will also be included in this group (see the names in [Appendix 1](#)). Depending on the development subjects, researchers in chemistry and specialists from other organizations are asked to participate as experts. In addition to the steering group, during the last ten years, the contact person from each cooperation partner has actively taken part in the practical forms of operations (see the names in [Appendix 1](#)), in collaboration with the coordinator.

1.3 Focus Areas of the Operations

Since 2017 the operations of ChemistryLab Gadolin have been directed by the **focus areas**¹² that have been approved by the executive board of the University of Helsinki's Science Education Centre. These have been formed based on the focus areas of the university and faculties for the strategy period of 2017-20 as well as on the themes of the national StarT operations¹³.

¹² helsinki.fi/en/science-education

¹³ start.luma.fi/en

The following have been **the three main focus areas during 2017-20** in ChemistryLab Gadolin's science education operations and in its research-based development:

- everyday chemistry
- sustainable chemistry and development
- modern technology.

The above mentioned focus areas direct the contents of study visits, operations in practice and development work in order to be able to develop new solutions and pedagogical innovations (see [Chapter 3](#) for more information). Most novel chemistry and research concerning its teaching as well as Finnish innovations in chemistry are taken into consideration in the implementation. In addition, the aim is to support the planning and implementation of core **curriculum** for chemistry in different school levels.

In the operations of chemistry science education, the following ways of execution are for example developed in its strategy period of 2017-20:

- inquiry-based and hands-on studying of chemistry and digital learning (such as microcomputer-based laboratory equipment, molecular modelling and 3D printing) that is based on the nature of the scientific process of chemistry
- taking into consideration the most novel innovations in chemistry and novel innovations in the industry
- chemical education that studies phenomena as entities and that integrates the different fields of science (and also technologies and disciplines)
- models for young chemical researchers taking part in science education (for example videos)
- different chemical professions in teaching (company gallery)

1.4 New Solutions and Pedagogical Innovations with Design-Based Research

Various research methods are used in ChemistryLab Gadolin in order to develop new solutions and pedagogical innovations (see [Figure 7](#)) – mainly the iterative method of the collaborative and engaging **design-based research**, DBR is used (see [Figure 8](#)). This does not only produce new and theoretical information into science education in chemistry and scientific papers, but it also produces new, practical solutions and pedagogical innovations that serve the operations, such as new learning environments, working methods or teaching material for teaching purposes. Based on the received theoretical research information, it is possible to further develop current and new forms of operation. In science education in chemistry, developed materials are spread out for everyone to use and by doing this scientific know-how is aimed at being strengthened.



Figure 7. In ChemistryLab Gadolin's science education, new solutions and pedagogical innovations are produced based on research (for example new, meaningful courses, inquiry-based work instructions and material for digital learning) for supporting science education in chemistry on different school levels, and also globally.

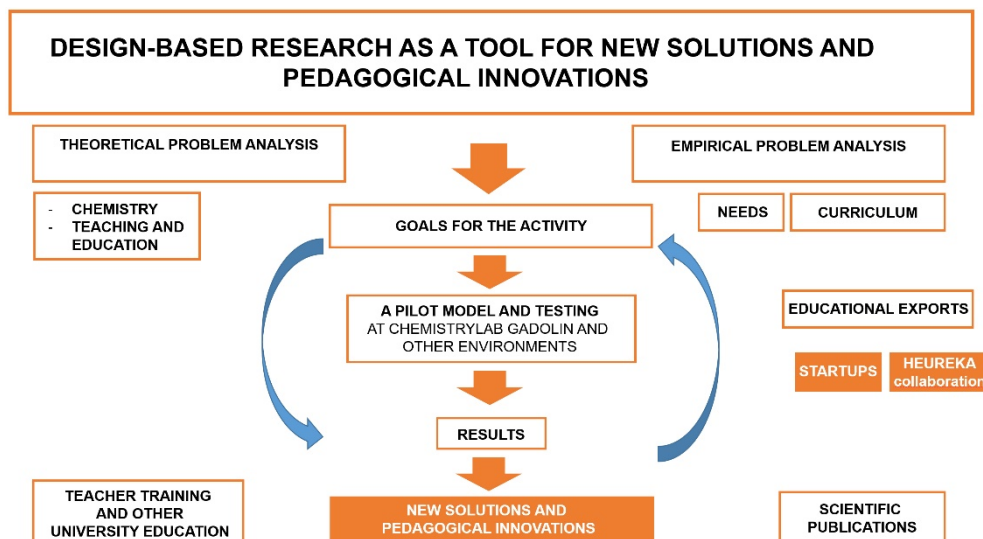


Figure 8. Design-based research is used in ChemistryLab Gadolin as a research method for the science education in chemistry in order to produce basic research information on a phenomenon and also to produce new solutions and pedagogical innovations into the teaching of chemistry. Numerous researches are made into theses at the Unit of Chemistry Teacher Education, and results are published internationally (see [Chapter 4](#)).

Engaging and collaborative design-based research acts as a **new kind of an education model for chemistry teachers** (see [Chapter 4](#)) for new solutions and pedagogical innovations. In this model, teachers and other cooperation partners learn from each other by reflecting on what they have learned in interaction.



Figure 9. The aim of science education in chemistry is through research and development operations to produce joy of insight and success for all and to support teachers in different levels in their important work. (Picture: Veikko Somerpuro)

2 CHEMISTRYLAB GADOLIN AS A PART OF NATIONAL AND INTERNATIONAL COLLABORATION

The Science Education Centre (a part of LUMA Centre Finland) and its ChemistryLab Gadolin collaborate with national and international partners and aim at reaching the goals by working together (see Science Education book by Aksela et al., [2018](#)). The science lab, ChemistryLab Gadolin has received the international Global Best Awards recognition for its collaborative operations in 2014. Here, in close interaction, it is possible to learn from one another and to reach a stronger effectiveness for the operations together.

This chapter introduces examples from a couple of significant national and international projects, where science education in chemistry has participated or is participating currently. The personnel from the Unit of Chemistry Teacher Education and postgraduate students have taken part in the implementation of most projects. The 15th Anniversary book of science education¹⁴ has been used partly as reference.



Figure 10. Each year hundreds of international visitors get acquainted with ChemistryLab Gadolin and its science education. The visitors in the above picture are from South-Korea. In the middle of the picture, you can see the director of ChemistryLab Gadolin, professor **Maija Aksela** as well as the coordinator from 2012-16 M.Sc. **Veli-Matti Ikävalko**, who held his doctoral dissertation on ChemistryLab Gadolin as a learning environment.

¹⁴ Collaborative Science Education: helsinki.fi/sites/default/files/atoms/files/isbn-978-951-51-4089-0.pdf

2.1 Background Information

The science education operations at ChemistryLab Gadolin are actively participating in both national and international collaboration. Versatile projects of science education and forms of collaboration have been collected in [Figure 11](#), where participation has occurred either partly or as the main impactor. The doctoral students at the Unit of Chemistry Teacher Education have participated in the practical coordination and directing of projects. These projects are described briefly in chapters [2.1](#) and [2.2](#).

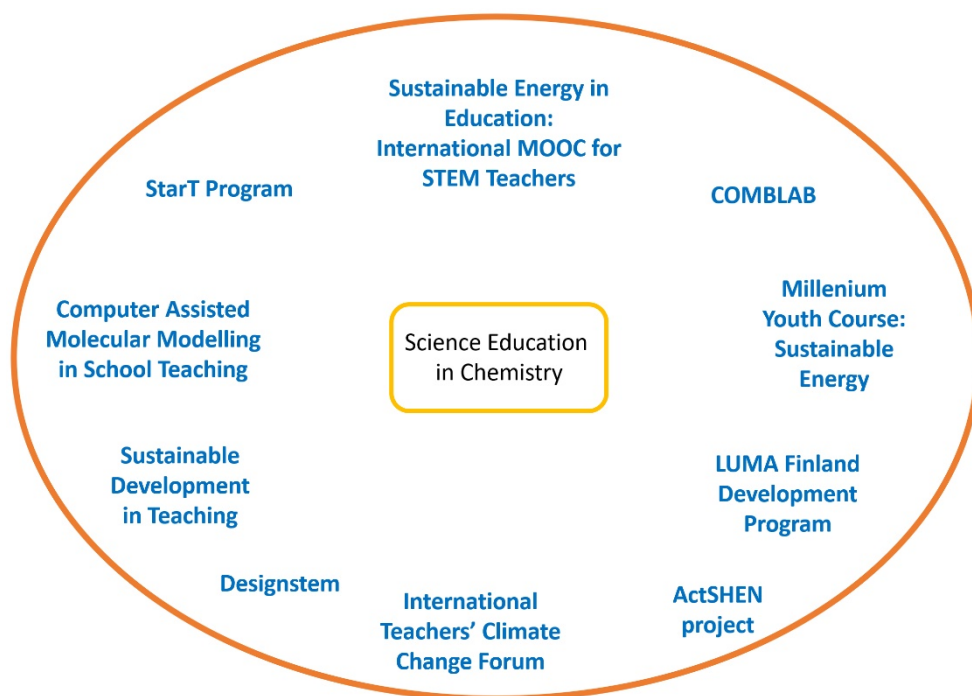


Figure 11. The operations of ChemistryLab Gadolin are a part of numerous national and international projects and this is how new solutions and pedagogical innovations are spread around to be widely exploited. The personnel of the Unit of Chemistry Teacher Education and postgraduate students act as central impactors for the projects. For example, in an EU Project **CombLab**, new inquiry-based work in the context of everyday chemistry was produced. More detailed descriptions of the projects can be found in chapters [2.2](#) and [2.3](#).

2.2 National Collaboration with the LUMA Centre Finland Network

National collaboration with the Science Education Centre and its ChemistryLab Gadolin is carried out mainly through 13 LUMA Centres that all belong under the LUMA Centre Finland network¹⁵ of 12 Finnish universities. Also, universities of applied sciences take part in the operations. During the years 2017–20, a **national purpose**

¹⁵ luma.fi/en/centre

is going to be carried out that the Ministry of Education and Culture has placed and that consists of six areas, one of which is the development of science lab operations all around Finland (see the book on science education by Aksela et al. [2017](#) for further information).

Science education in chemistry is promoted collaboratively through numerous national projects. For example, through the national LUMA FINLAND development program¹⁶, teachers are educated on new openings that have been developed in the program together with postgraduate students of the Unit of Chemistry Teacher Education. These projects support significant implementation of the revised core curriculum. Science education in chemistry is promoted especially in four projects (there is also a possibility to receive online training concerning these projects):

- Everyday life phenomena
- Good question!
- Mathematics and natural sciences in society: collaborative studying with the working life
- Research and ponder: researching skills of pre-schoolers

In a national development and research project (2008-11) **Computer-assisted molecular modelling in school teaching**, it was possible to include molecular modelling that is central in chemistry, as a part of school teaching and teacher education. In the project Computer-assisted molecular modelling in school teaching:

- pedagogical solutions and approaches into the teaching of chemistry were developed based on most novel research information nationally and internationally in cooperation with eager school teachers
- mentors of molecular modelling were educated all around Finland. They acted as instructors and support persons in their own areas
- open teaching material was produced online for teachers that supported the use of molecular modelling
- research was conducted on the possibilities of the approach and its effectiveness in the learning and teaching of chemistry.

Several publications were compiled from the research carried out during the project, a doctoral dissertation was also written based on the project (Aksela & Lundell, [2008](#); Aksela, Lundell, & Pernaa, [2008](#); Pernaa, [2011](#); Pernaa, Aksela, & Lundell, [2009](#)). The results have been taken widely into use in several schools, in teacher education and in ChemistryLab Gadolin¹⁷. In 2017, know-how was spread out

¹⁶ suomi.luma.fi

¹⁷ helsinki.fi/en/science-education/for-teachers/group-visits-to-science-labs/chemistrylab-gadolin

internationally in the form of a non-fiction book that was written in English (Perna, Aksela, & Ghulam, [2017](#)).

2.3 International Collaborative Projects

In science education in chemistry, participation in international collaboration is active. Up until now, participation has occurred in the following international projects (in alphabetical order): the Nordic **ActSHEN** project as well as the EU projects **COMBLAB** and **Designstem**, in addition to the international StarT (see [Chapter 2.2](#)).

Action for Sustainability in Higher Education in the Nordic region (ActSHEN)¹⁸ is a Nordic collaboration and research project that took place during 2013-17, where a model for supporting sustainable development in higher education, was developed (Heiskanen, Käyhkö, & Virtanen, [2017](#); Tolvanen, [2016](#); Tolvanen & Aksela, [2013](#)). In this project, new approaches have been developed into teaching about sustainable development, which have been applied in various ways in participating institutions as well as in a course ***Sustainable development in teaching*** for pre-service teachers at the University of Helsinki.

In an EU funded **COMBLAB collaborative project** (2012-14) that was carried out in collaboration with specialists from Austria, Czech Republic, Finland, Slovakia and Spain, several types of inquiry-based work for lower secondary level students and mainly for the teaching of chemistry were developed in collaboration with researchers and teachers from universities. These inquiry-based works exploited information and communications technology and were based on microcomputer-based laboratory. In addition in the project, teachers were educated to use them and research was conducted on the effectiveness of the project (Tolvanen, Aksela, Guitart, & Urban-Woldron, [2014](#)). Here, a research conducted in 2011 at the University of Helsinki was exploited (Aksela, [2011](#)). It is still possible to do most works that were developed during the project, at the ChemistryLab Gadolin and these works are also used in pre-service teacher education.

An ongoing project of science education is the EU project **Designstem**¹⁹ (2016–19), the aim of which is to develop electronic learning materials that combine design and natural sciences, such as games, mobile applications or interesting electronic learning materials.

The promotion of education on sustainable development is a central focus area in science education in chemistry. Research is conducted on the topic and theses are written, for example doctoral theses (Juntunen, [2015](#); Tolppanen, [2015](#)). New virtual operating models for sustainable development and its promotion for both youth and teachers, have been researched and developed in a virtual science

¹⁸ blogs.helsinki.fi/action-for-sustainability

¹⁹ bit.ly/2DdLOfe

education project. Up until now, three national parts of the project have been carried out: (i) *Millennium Youth Course: Sustainable Energy*²⁰ (Aksela, Wu, & Halonen, 2016) that is aimed for the youth, (ii) *Sustainable Energy in Education: International MOOC for STEM teachers* (Kaul, Aksela, & Wu, 2018) that is aimed for teachers, and (iii) *International Teachers' Climate Change Forum*²¹ that is aimed for teachers. The know-how of doctoral students at the Unit of Chemistry Teacher Education and their research concerning their doctoral theses have been exploited in science education in planning and carrying out of projects.



Figure 12. Meaningful, inquiry-based work instructions that concern everyday chemistry have been developed for children and youth in different levels for example in the EU project **CombLab**. (Pictures: Pipsa Blomgren (above), Sonja Martikainen (below))

²⁰ luma.fi/en/news/2015/10/28/millennium-youth-course-sustainable-energy

²¹ luma.fi/en/event/international-teachers-climate-change-forum

3 CHEMISTRYLAB GADOLIN AS AN INSPIRING LEARNING ENVIRONMENT FOR CHILDREN AND YOUTH

In this chapter, the aims of science education of the popular ChemistryLab Gadolin are going to be described. Also, the significance of the operations through conducted research and main forms of operations are introduced through examples. During the past 10 years, more than 50 000 visitors (up to 4 000 children and youth per year) have visited the popular science lab ChemistryLab Gadolin.

3.1 Aims and Significance of the Operations

The main aim of science education of ChemistryLab Gadolin is to promote and support the teaching of chemistry and the curriculum on the three levels of relevance (see [Figure 13](#)): (i) **individual relevance**, (ii) **societal relevance** and (iii) **vocational relevance**. It aims at inspiring children and youth towards studying chemistry and increasing the hobby-ism of chemistry through new and inspiring inquiry-based work, computer-assisted modelling, researcher meetings and through professional images of chemistry, and at supporting teachers and pre-service teachers in carrying out meaningful teaching of chemistry and lifelong learning.

Everyday chemistry, sustainable chemistry and development as well as **modern technology** are the main themes for the operations and its research-based development during the strategy period of 2017–20. Close collaboration with the Unit of Chemistry Teacher Education supports the operations through most novel teaching and learning and through research concerning teacher education and theses (see [Chapter 4](#) for further information).

Science education at ChemistryLab Gadolin has been discovered as important both in the sense of feedback surveys and research concerning it. The popularity (a maximum of 4 000 children and youth each year) of the hands-on study visits taking place at the modern ChemistryLab Gadolin and the annually received encouraging feedback based on surveys for both teachers and students shows that it reaches the set aims and also the challenges that have been taken into consideration in the teaching of chemistry (see [Chapter 1.1](#)). Also, positive feedback has been received from the steering group of ChemistryLab Gadolin (see [Appendix 1](#)). The effects of ChemistryLab Gadolin have been studied in more detail in several researches and theses (see [Chapter 4.4.1](#)). The operations of Gadolin have also a central role in pre-service and in-service chemistry teacher education and in its chemistry education research.

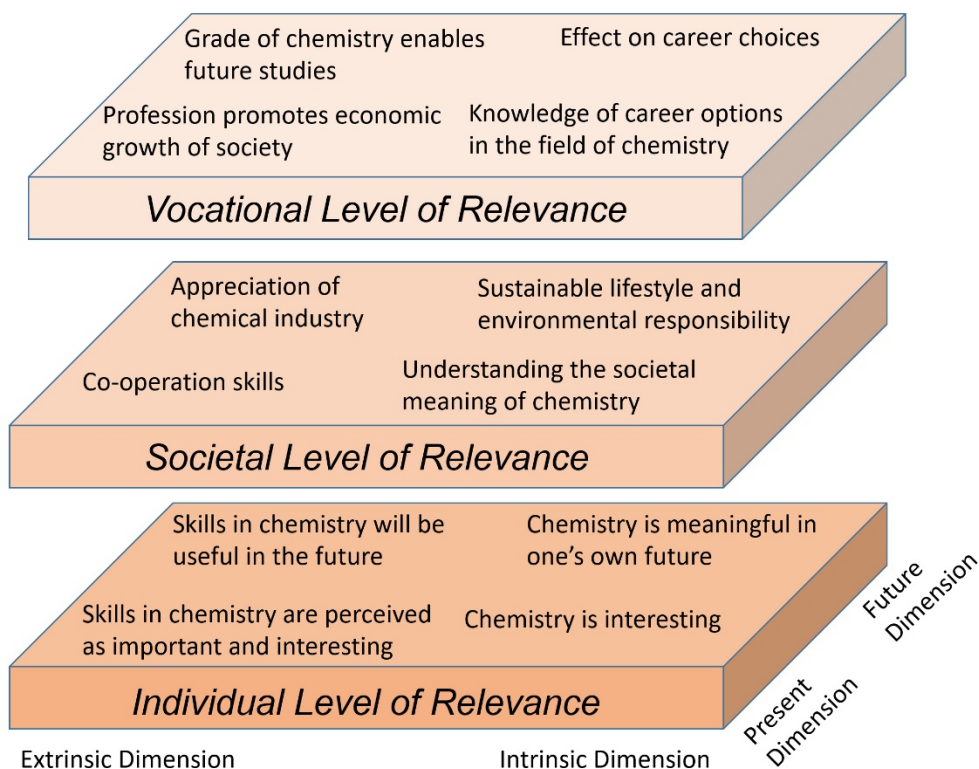


Figure 13. The different dimensions and components of the relevance theory (Stuckey, Hofstein, Mamluk-Naaman, & Eilks, 2013).

3.2 Target Groups

The science lab ChemistryLab Gadolin and the different forms of operation of its science education serve the teaching of chemistry on different levels from early childhood education to the upper secondary level (see [Figure 14](#)). **The target group consists of 3-19-year-old children and youth and their teachers in different school levels.** Also, different operating models of science education for families are being developed during the coming years. For example, during Summer 2018, science camps for families were tested for the first time, in which children, parents or grandparents have the possibility of participating together with their child.

During these 10 years, of all the school levels the biggest user group has consisted of primary level students (68%), where an important base for the bright future of chemistry is being built. Since 2015, the possibilities of early childhood education in developing children's skills in research in the context of everyday life phenomena has been emphasized. Physically and virtually popular *Small Jippos* science clubs have been organized for small children on the basis of research (see the book on science education for further information, Aksela et al., (see Aksela et al., [2018](#))).

Figure 14. The target groups and the number of participants (%). During the past 10 years, a maximum of 4000 children have participated annually. Kindergarten groups have had a possibility to visit since 2015.

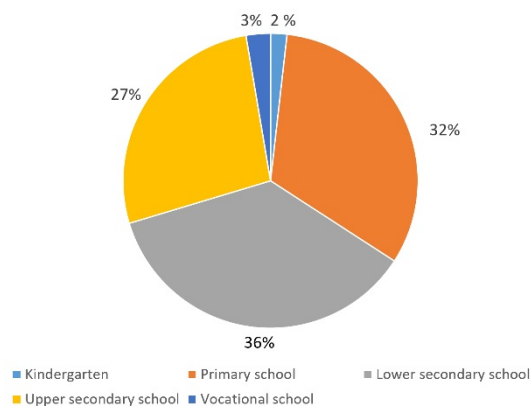


Figure 15. The operations of ChemistryLab Gadolin especially support 3-19-year-old children and youth as well as their families' science education in chemistry and teachers' lifelong learning. Such forms of science education, where children and their grandparents work together, are being developed based on research. The aim is also to promote multicultural science education. (Pictures: 3rd ja 6th Veikko Somerpuro, 4th Sakari Tolppanen, 2nd Elisa Lautala)

3.3 Forms of Operation

Versatile forms of operation, also virtual, are being used in science education at ChemistryLab Gadolin (see [Figure 16](#)). In the following chapters 3.3.1–3.3.6, the forms of main operations are described, and examples are given of practice that has been perceived as successful.

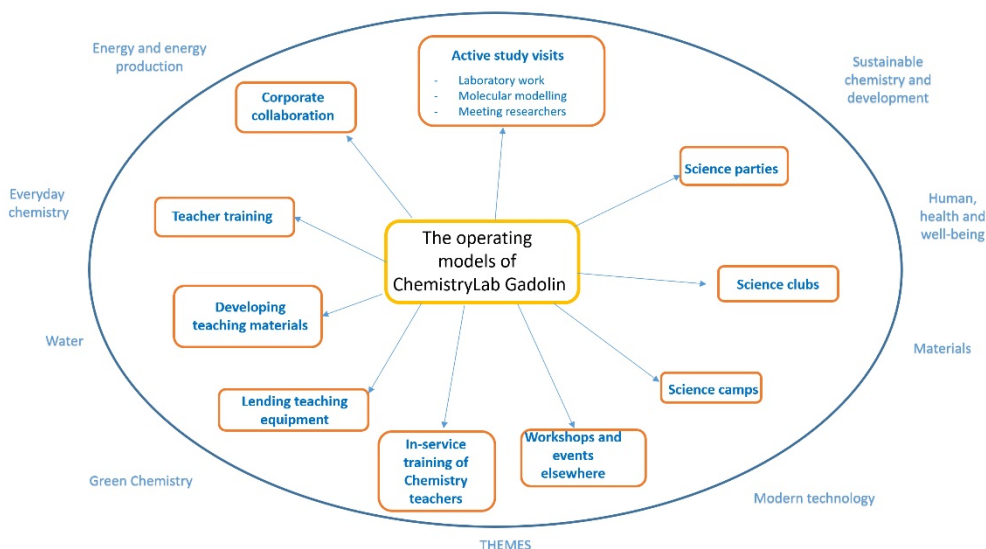


Figure 16. Forms of operation for science education in ChemistryLab Gadolin are carried out in strong interaction with pre-service and in-service education and research at the Unit of Chemistry Teacher Education as well as with the Department of Chemistry and the Industry (see [Chapter 4](#) for more information). The focus areas of the operations (the themes) are defined according to the University's strategy periods.

3.3.1 General Information

The aims of the operations of the Science Education Centre guide the operations of ChemistryLab Gadolin (see [Chapter 1.3](#)). The focus areas of the operations (the themes) are defined according to the University's strategy periods.

During the years 2018–2020, especially the following are emphasized as focus areas: everyday chemistry, sustainable chemistry and development and modern technology. Most novel research information in chemistry and its teaching as well as innovations are taken into consideration in their implementation. In the international chemistry operations in 2011, the main theme was water. During 2008–2017, the themes focus for example on everyday chemistry, different materials and their chemistry, energy and energy production, green chemistry, chemistry concerning us humans, health and wellness as well as the chemistry of water.

Hands-on **study visits** (see [Table 1](#)), make up the main operating form of ChemistryLab Gadolin, during which teaching groups of different levels, from early

childhood education to universities, have a possibility of getting to know new openings in the science education in chemistry by doing things themselves.

Table 1. The main forms of operation and target groups of science education in chemistry at ChemistryLab Gadolin.

Forms of operation		Target group (to whom the activities are aimed at)
Hands-on study visits	Inquiry-based laboratory work	Children and youth Teachers and instructors
	Computer-based visualization	
	Visits and meeting with researchers	
Gadolin club		Youth
Science birthdays (since 2012)		Children and youth Families
Science clubs		Children Families
Science camps		Children and youth Families
Science briefcases that can be borrowed		Children and youth Teachers and instructors
Corporate collaboration		Children and youth Teachers and instructors
Collaborative courses		Youth Teachers and instructors
Teachers' in-service education		Teachers and instructors
Development of hands-on study visits and their activities		Children and youth Teachers and instructors
Workshops elsewhere		Children and youth

During a study visit, children and youth complete inquiry-based work in an actual laboratory concerning the themes of the year, or they get to explore the possibilities of molecular modelling in a computer classroom, which itself is important in chemical research. In addition, visitors have the possibility of meeting researchers and visiting their research laboratories and to gain information about the field of chemistry and studying chemistry. Visiting groups are instructed by a pre-service teacher or a chemist that has received education for the job (Figure 17).

Hands-on study visits are built to support the aims of teaching of the visiting teacher and the visiting school's curriculum for chemistry. Usually **visits consist of three stages:**



Figure 17. In Gadolin, visitors are instructed by pre-service teachers or chemists that have received education for the job. In the above picture, there are instructors from 2016. Pipsa Blomgren, on the right, has been the coordinator since 2017.

- (i) Getting acquainted with the theme and visit at school
- (ii) a hands-on study visit in ChemistryLab Gadolin (usually between 2–4 hours)
- (iii) compilation and evaluation at school (e.g. as a part of course evaluation).

The teacher contacts the coordinator with an electronic form that can be found online²² after which the planning process of the visit begins. Visits are instructed by instructors, future chemistry teachers or future chemists, who have received education concerning the job. The **visiting calendar** and a **work instruction bank** can be found in the website²³ of ChemistryLab Gadolin.

²² helsinki.fi/en/science-education/for-teachers/group-visits-to-science-labs/chemistrylab-gadolin#section-33767

²³ kemianluokka.fi

Table 2. Examples of carrying out hands-on study visits at the ChemistryLab Gadolin that support the curriculum for chemistry.

	Stage 1 Getting acquainted with the theme and visit at school	Stage 2 A hands-on study visit at ChemistryLab Gadolin (usually between 2–4 hours)	Stage 3 Compilation and evaluation at school
Primary school	The teacher reserves the study visit beforehand and wishes for contents that are suitable when considering the skills of the group and a theme that follows the curriculum, as well as a meeting with a researcher on the field of chemistry. In school, the teacher goes over (with the group) e.g. prior assignments concerning the inquiry-based work and together they ponder on questions that could then be presented to the researcher.	Gadolin instructors welcome the group and go over the contents of the prior assignments with the group and give instructions concerning the inquiry-based work. After completing the work, themes that arose during the work are looked at together in the group. After the laboratory part, the group meets with a researcher, who tells the students about their work and gives answers to students' questions.	After the study visit, the teacher can return to the theme of the visit in their own teaching and by doing this exploit the students' experiences that they gained during the visit, when they return to the topic later in coming school years.
Lower secondary school	The teacher reserves the study visit for the last lesson of the course, after the final exam just before the vacation. Because all contents of the curriculum have already been covered during the course and the evaluation is finished, the Gadolin instructors have free hands to plan the contents for the study visit. The aim of the visit is to interest students, to offer memorable experience among chemistry and to revise learned contents in a fun way.	Gadolin instructors have planned an unforgettable visit for the group that consists of hands-on and fun, inquiry-based work and demos that are suitable for the age group. The themes of the completed activities have to do with things that the group has already learned and they offer new viewpoints into what has been learned beforehand. Such substances and equipment are used in the activities that are rarely seen in school teaching, such as liquid nitrogen and dry ice.	The study visit will be remembered by the students as an inspiring and a fun example of chemistry as a subject. The teacher can return to these images and support the enthusiasm of students in school after the vacation.
Upper secondary level	The teacher reserves the study visit as a part of teaching and course plan and choose those inquiry-based works from Gadolin that support the contents of the course and that cannot be completed in schools. For example, in a course on organic chemistry, in the previous lesson students had synthesized samples of aspirin and they take them with them to be analyzed with the IR spectrometer in Gadolin. In addition, the teacher wishes that during the visit there would be molecular modelling in a computer lab, as well as a meeting with a researcher on the field of chemistry.	As the group arrives in Gadolin, the instructor goes over theory concerning the inquiry-based work and gives instructions for carrying out the work. Students work independently with the open assignment, during which the teacher and Gadolin instructor go around helping. For example, the instructor first goes over how the IR spectrometer works and then opens theoretical concepts and helps with reading the spectrum. In a computer lab, the group gets to model the known molecule from the inquiry-based work, aspirin with the modelling program Spartan. At the end of a study visit the group meets with a researcher that tells about their topic of research and their educational history.	At school, the teacher can give further information concerning the theory part, if they see it fit. Students are assigned to write a work report based on the completed inquiry-based work in Gadolin that will be graded as a part of the course.

In hands-on study visits to ChemistryLab Gadolin, a research-based approach is emphasized, and visitors are motivated towards chemical research and learning of chemistry. With the help of computer-based visualizations such as **molecular modelling**, animations and simulations, the understanding of phenomena discovered during inquiry-based work is supported. Meetings with researchers and visits to the research laboratories at the Department of Chemistry as a part of a study visit, support the development of the nature of chemical research and its significance and they also offer positive experience in an actual researcher environment. Children and youth may also be able to get important role models that inspire towards studying chemistry.

Hands-on study visits have the possibility of reaching all the levels of relevance of the relevance theory by Stuckey et al. (2013) (see [Chapter 3.1](#)). With the help of inquiry-based work, it is possible to reach the level of individual relevance, because students mostly experience inquiry-based work as interesting. In the working instructions concerning inquiry-based work, usually the actual problem of the field of chemistry is introduced, which is then possible to be solved with the help of know-how of chemistry and skills. In such a situation, during the study visits it is also possible to reach the levels of societal and vocational relevance in addition to the individual relevance. Presentations on the field of chemistry held on the study visits, hearing about study possibilities and meeting with researchers also increase **the relevance of ChemistryLab Gadolin as a learning environment on all levels of relevance**.

ChemistryLab Gadolin also offers support for choosing a career and for the study possibilities of the field of chemistry and offers support for the visitors and additional material for the planning of studies. In presentations that are held alongside visits, the field of chemistry and study possibilities are described thoroughly and the possibilities of chemistry are mentioned. In cooperation with collaboration companies, a so-called company gallery has been built that consists of videos on different chemical professions in various companies.²⁴

In his doctoral thesis, Ikävalko (2017) developed operating models alongside study visits. The work instructions that Ikävalko had developed in corporate collaboration were made to resemble the developed operating models, and for example the *Hardness of water* work instruction developed together with Oy Aga Ab consists of the following three stages: 1) a stage that sets the work in motion and that consists of questions to ponder about, which the teacher then can give for example as homework before the hands-on study visit, 2) the steps of the work instruction that is going to be completed during the hands-on study visit as well as questions with which it is possible to go over the work after completing the work and 3) four additional exercises have been collected at the end of the work instruction that students can complete at home.

²⁴ [youtube.com/results?search_query=kemian+osaajia](https://www.youtube.com/results?search_query=kemian+osaajia)

3.3.2 Inquiry-Based Learning

The aim of ChemistryLab Gadolin is especially to **promote the meaningful inquiry-based learning of chemistry**. In its operation, the aim is to develop new openings within the framework of the themes, with different cooperation partners (see [Table 3](#)).

Table 3. A couple of examples of inquiry-based work instructions that were developed during 2018-19 that the visitors get to complete during their hands-on study visits. Most works are connected to thesis research.

Theme	Inquiry-based work	Target group
Everyday chemistry	Art with the means of chemistry	Kindergarten and primary school
	Shampoo that surrounds dirt	Lower secondary school
	A tricky day as a pharmaceutical producer in a pharmacy	Lower and upper secondary school
Sustainable chemistry and development	Studying water	Kindergarten and primary school
	From aluminium to alum	Lower and upper secondary school
	Researching the quality of water	Lower and upper secondary school
	Green laboratory	Upper secondary school
Modern technology	Molecular modelling on the MarvinSketch	Lower and upper secondary school
	Art with the means of chemistry	Upper secondary school

The visitors get acquainted with these by doing things themselves and at the same time by giving feedback they promote their development. Most new openings are a part of theses. For example the popular hydrogen car activity has been developed through design-based research (for example Aksela & Boström, [2012](#)).

Children and youth are instructed during inquiry-based work by trained pre-service teachers or chemists. The instruction for inquiry-based work mainly takes place in the facilities of the University. In 2015 when Gadolin was under construction, instructors went around in schools and kindergartens and instructed inquiry-based work. The teacher of the visiting group has the possibility of concentrating on observing and reflecting on the students' learning and at the same time they can learn from the students as well as about the new theme. In a way, this possibility is a new kind of a model for in-service education for teacher education (see more in [Chapter 4](#)).



Figure 18. During a hands-on study visit, ChemistryLab Gadolin offers the possibility of exploring new openings. Future chemistry teachers and researchers from the University or the Industry participate with the development and implementation of works.



Figure 19. The water analysis briefcase is one of the most popular teaching packages from the packages that are lent. It is used to study the chemical properties of water, also in the nature.

3.3.3 Molecular Modelling and Other Kinds of Digital Learning

The versatile implementation of information and communications technology in the teaching of chemistry has been promoted in science education in chemistry since 2002 in collaboration with the Unit of Chemistry Teacher Education.²⁵ Especially the development and promotion of molecular modelling (Perna, [2011](#)) and microcomputer-based laboratory (Aksela, [2005](#)) in the teaching of chemistry has been progressive both nationally and internationally.



Figure 20. In-service education on molecular modelling for teachers. (Picture: Sakari Tolppanen)

A part of the molecular modelling assignments in ChemistryLab Gadolin have been developed together with Gadolin's collaboration companies. This creates new possibilities in strengthening the scientific know-how of chemistry. For example, the activity *Building blocks of polymers* has been developed with specialists from Borealis and the *Superabsorbents* with specialists from BASF Oy. **This is how different educational institutions get to work with authentic activities concerning modelling.** Gadolin offers suitable molecular modelling themes for all school levels: students on the primary and lower secondary level can work with atoms, molecules, polarity and surface tension, and students on the upper secondary level usually choose to model the molecular orbitals and simulate the molecular vibrations of IR

²⁵ LUMAT Special Issue: Promoting innovative and collaborative chemistry education through evidence-based chemistry teacher education. LUMAT, 1(3) (2016). umat.fi/index.php/lumat-b/issue/view/2

spectroscopy. During the academic year of 2018–2019, MOOCs for teachers are being developed concerning the use of molecular modelling and microcomputer-based laboratory in the teaching of chemistry. These are developed as a part of the University of Helsinki's Digiloikka (A jump into the digital world) project. The courses are published on the University of Helsinki's MOOC platform.²⁶

The next and new subject of development for modern technology is **3D printing** in chemistry teaching. This research topic in researching the teaching of chemistry is entirely new, since it has not been studied that much before. A Master's Thesis is on the way on the topic, where suitable teaching models for exploiting 3D printing are developed on the basis of research. Design-based research is conducted in collaboration with ChemistryLab Gadolin, in such a way that the student groups and teachers visiting Gadolin get to test the developed works. With the help of this research process, teaching models for 3D printing that are suitable to the needs of the field are developed that are then spread around for teachers to use globally.

3.3.4 Exploring the Research of Chemistry and Researchers

It is possible to get to know the most novel research in chemistry and to get acquainted with researchers in the form of a hands-on study visit or as a part of a study visit. The aim is to organize this according to the wishes of the teacher, while planning the study visit. It is wished for that the visit would support the implementation of the aims of chemistry teaching according to the school's curriculum. Usually the visiting students get to know the theme beforehand at school. They can for example send questions to the researcher beforehand that they wish the researcher to answer or talk about during the meeting.

Meetings with researchers are planned with the teachers so that the researcher's specialization would resemble the taught topic or a topic that the group is especially interested in, which then makes it possible to look at and understand contexts on a deeper level. **Meetings with researchers usually consist of an introduction on the researched topic, a tour of the research laboratory and telling about their research in more detail to the visiting group and answering questions that arise.** Meetings with researchers may possibly be longer and they can be organized in a lecture format, where their research and the methods used are described in more detail.

In Fall 2017 and 2018 ChemistryLab Gadolin has organized for example a course *Chemistry of health and wellbeing* in collaboration with Ressu upper secondary school. The aim of the course was to present current research in the field of chemistry in the contexts of health and wellbeing. The course consists of lectures held by young researchers in the field of chemistry and other specialists, through which upper secondary level students will get a thorough and a current picture of chemical research and of various career possibilities.

²⁶ blogs.helsinki.fi/mathedgroup/projects-hankkeet/aineenopettajakoulutuksen-digiloikka

Researchers act as role models for the makers of the future. Getting to know novel research information helps the teacher to update their know-how of chemistry and to take the new information into consideration in future teaching. At the Department of Chemistry, it has been possible since the 1980's to get to know research. Forms of collaboration, where young researchers in chemistry are a part of science education activities, is going to be developed even more in the future.



Figure 21. A researcher is encouraging upper secondary level students towards studying chemistry.
(Picture: Veikko Somerpuro)

3.3.5 Science Clubs, Science Camps and Science Birthdays

Science education in chemistry is promoted also in the forms of science clubs, science camps and science birthdays. The aim here is to develop new and significant openings into chemistry teaching and to inspire the participants towards studying chemistry.

Science clubs that are aimed at primary level students, Gadolin clubs that are aimed at youth as well as science camps that are aimed at both groups, support interest towards chemistry and they enable encouraging experience of working in a chemistry laboratory. Gadolin clubs offer a meeting place, where youth get to know researchers and current research concerning natural sciences. In these clubs, youth meet scientist, both men and women, and they hear about the research, Industry, study possibilities and international operations on the field.

Science clubs, camps and birthdays are a part of the ongoing operations of ChemistryLab Gadolin. All of these forms of operations are organized with changing themes. These have been among others, mystery, chemistry and art, tasty molecules,

and materials. See more information about science clubs and camps of chemistry from Science Education Centre's anniversary book (Aksela et al., 2018)²⁷

In science parties organized in ChemistryLab Gadolin, children and youth have the possibility of dressing in a white researcher's jacket and to work with their friends in an authentic laboratory. Different kinds of ready-made science party packages with different themes are offered (see [Table 4](#)). It is also possible to customize a party according to the age of the guests, wishes and interests. Under the instruction of educated instructors, researching and solving challenges concerning researching is both fun and safe.



Figure 22. In the Small Jippo's science club, 3–6-year-old children get to know phenomena in chemistry and researching skills through researching assignments that include a storyline.

²⁷ helsinki.fi/sites/default/files/atoms/files/isbn-978-951-51-4089-0.pdf

Table 4. Science birthdays inspire children and youth with their families towards intriguing chemistry. They are offered to adults as well. Development and research operations are connected to the themes.²⁸

Inquiry-based work	Target group
Chilly Chemistry	The world of liquid nitrogen and dry ice is going to be explored.
Detective	The detectives work together and solve a mystery with the help of natural sciences.
Feelings and scents	For example, sweet-smelling bath bombs are made.
Tasty molecules	The secrets of molecular gastronomy are explored by preparing e.g. ice cream or sorbet.
Colorful chemistry	Different experiments and demonstrations are conducted, in which colors play a central role.
Jumpy molecules	Students get to make a superball and slime
Escape room	The way out of a mysterious escape room is revealed by solving various assignments together.

3.3.6 Other Events of Science Education

In events and seminars of science education of chemistry, workshops and demonstrations are organized for different target groups from small children to teachers and from the public to the specialists in chemistry. In workshops, phenomena in chemistry are explained and taught in a way, in which the participants actively participate in the learning situation. The demo shows amaze and make chemistry fascinating, because some of the information is left for the viewer to figure out themselves.

The instructors of ChemistryLab Gadolin have for example been organizing a workshop in the **Night of the Arts** for several years in collaboration with the Finnish Chemical Society and also in the European Researcher's Night that is organized in the University of Helsinki's Observatory. In addition, close collaboration occurs in different teachers' in-service education events organized by Heureka, the Finnish Science Centre, events such as *Circular economy for teachers* educational event.

One highlight of science education of ChemistryLab Gadolin has been a **short play of the life work of A. I. Virtanen**²⁹ that was made in honor of the International Year of Chemistry 2011 together with the Unit of Chemistry Teacher Education with Ilkka Pollari as the scriptwriter. Among others, future chemistry teachers played roles in the play. A video of the play is available online for supporting school teaching.³⁰

²⁸ Science parties: helsinki.fi/en/science-education/children-and-young-people/science-parties

²⁹ portal.mtt.fi/portal/page/portal/Artturi/artturi_web_service/xvi_international_silage_conference/programme/virtanen_play

³⁰ youtube.com/watch?v=Gv3GZ1Vn8d8



Figure 23. Science education of chemistry with the means of drama. In the International Year of Chemistry in 2011, a play about A.I. Virtanen, a chemist who was awarded with the Nobel Prize, was carried out. It was performed to the public three times, and a recording of the play is available online. In the above picture, Jan Jansson, a student studying to be a chemistry teacher, played the role of the Nobelist.

4 CHEMISTRYLAB GADOLIN IN TEACHER EDUCATION AND IN ITS RESEARCH

This chapter describes, how the promotion of science education in chemistry is carried out in collaboration with the Unit of Chemistry Teacher Education that operates at the Department of Chemistry. For example, research concerning the teaching of chemistry is an important target of collaboration. Also, the most novel information of international and national research on the teaching of chemistry and collaboration networks, is in the hands of ChemistryLab Gadolin's science education operations.

In courses concerning the teaching of chemistry, future chemistry subject teachers get to plan, instruct and develop hands-on study visits to ChemistryLab Gadolin as a part of their studies. In addition, the science lab offers a possibility for conducting research, collecting a broad amount of research data and for analyzing it. This collaboration supports the constant development of ChemistryLab Gadolin that supports science education. It is also possible to complete projects concerning theses in collaboration with companies, equipment manufacturers and other cooperation partners. This is how research and design-based research can be better allocated to most novel innovations in the field of chemistry and how they can be spread into school teaching.



4.1 General Information

ChemistryLab Gadolin is exploited in a versatile way as support for the development of chemistry teaching, its research and education (see [Figure 25](#)) (Aksela, [2010](#), [2016](#)). The science lab is an inspiring learning environment for future chemistry subject teachers that receive teaching experience from working there and they learn about chemistry and of its activities, while they instruct study visits as a part of assignments for their chemistry courses (see [Chapter 4.2](#)).

For chemistry teachers that are working in the field and that observe Gadolin visits, while future teachers are instructing the visits, this offers a **new kind of a model of in-service education for chemistry teaching**: the teacher learns while they observe and reflect on the students' work and at the same time gets acquainted with a new theme. Through ChemistryLab Gadolin's science education, in-service education is offered for new openings and pedagogical innovations, in which subject teachers in chemistry usually act as instructors. At the same time during the education, both can learn from one another. In-service education is a perfect place for networking, where chemistry teachers and teacher students meet each other along with specialists from companies on the field of chemistry and specialists in chemistry from the University of Helsinki (see [Chapter 4.3](#) for more information).

In addition to the educational operations, Gadolin is important from the viewpoint of the promotion of chemistry teaching. Future researchers of chemistry teaching and teacher researchers **practice conducting research** in chemistry teaching courses by conducting small researches during Gadolin study visits. Depending on the course, students research phenomena on the teaching of chemistry from the viewpoint of a theory (e.g. interest in chemistry, motivation, attitude and relevance). Through conducting small researches, students gain tools and the courage for completing theses at the end of their studies. In addition, they have several possibilities of conducting research concerning the teaching of chemistry, which then prepares them for a future career as a researching teacher or a researcher. They grow into so-called researching chemistry teachers for lifelong learning (Aksela, 2010).

ChemistryLab Gadolin supports the development of chemistry teaching by offering possibilities for writing theses. Thousands of teachers and students that visit Gadolin yearly make it possible to collect broad amounts of research data and therefore enable quality research to be conducted by the postgraduate students and researchers in the Unit of Chemistry Teacher Education at the University of Helsinki (see [Chapter 4.4](#) for more information). Gadolin is an important link between teachers working in the field, since visiting teachers continuously tell about the development and research needs of school teaching of chemistry for teachers in the field. (Affeldt, Tolppanen, Aksela, & Eilks, [2017](#); Aksela & Ikävalko, [2016](#); Aksela, Vartiainen, et al., [2016](#))

In the science education operations of ChemistryLab Gadolin, **the alumni operations** of chemistry teachers are going to be strengthened even more in the coming years. The Alumni are sent e.g. current information about research in the field,

educational possibilities and events through alumni letters. In addition, hands-on study visit possibilities are made possible first for the chemistry teachers that have graduated from the Unit and only then to other teachers.

ChemistryLab Gadolin's science education is also participating in the development process of **MOOCs** that are aimed at teachers, in collaboration with doctoral students and researchers at the Unit of Chemistry Teacher Education. Up until now, the following courses have been developed: *Sustainable Energy in Education*, *Everyday phenomena and multidisciplinary projects in the teaching of LUMA subjects*, *Exploiting questions and argumentation in the school teaching of natural sciences*, *Science and technology education* and *Molecular modelling in the teaching of chemistry*. Next there will be courses on sustainable chemistry. Gadolin's operations support the development of courses especially concerning the expertise regarding inquiry and molecular modelling.

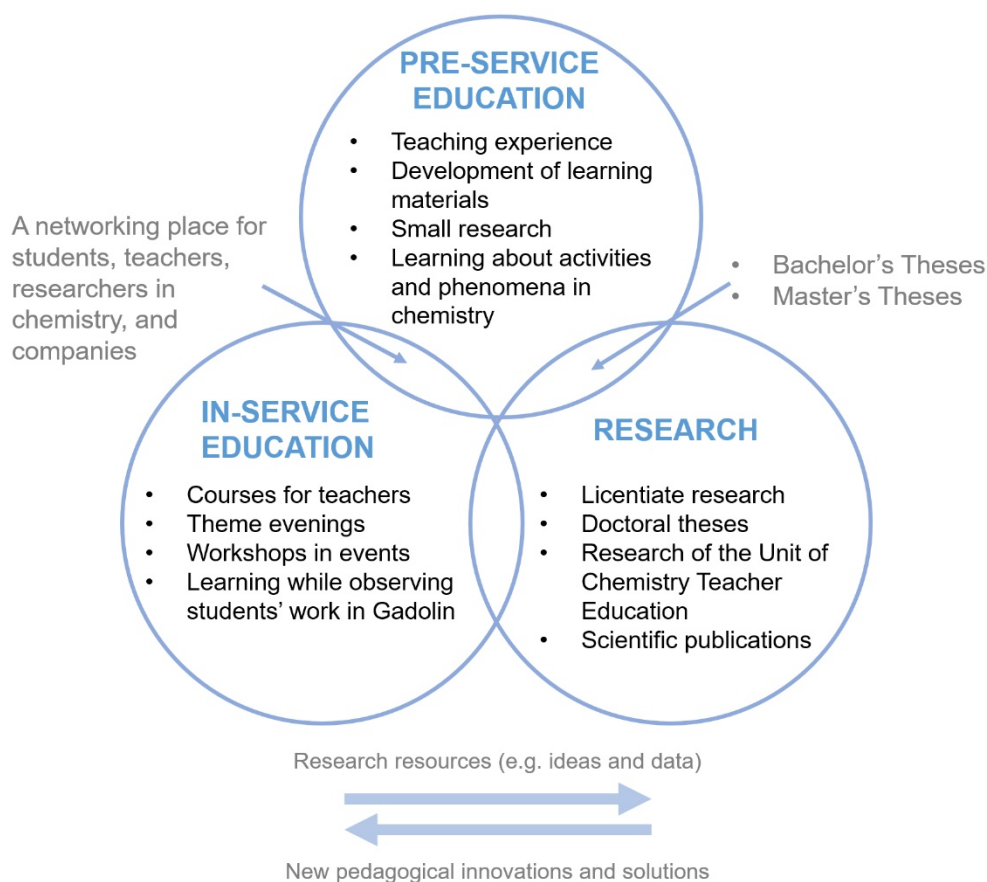


Figure 25. ChemistryLab Gadolin acts as an environment for education and research of science education in chemistry, which gives us new solutions and pedagogical innovations for strengthening the scientific know-how of chemistry.

4.2 Collaborative Models in Teacher Education

ChemistryLab Gadolin has been operating closely as a learning environment for chemistry teacher education at the University of Helsinki since its year of foundation in 2008. In several courses on chemistry teaching, an individual and inquiry-based teaching entity is planned and carried out as a part of study visits at ChemistryLab Gadolin (see [Figure 26](#)). This is connected to the topic studied in the course, and they are reported on according to the instructions of the assignment. The teaching entities are planned in collaboration with the teacher of the visiting group, so that the entity is lined with the group's learning goals and contents. A collaborative model would enable the fact that a teacher can exploit the study visit also as a part of course evaluation.

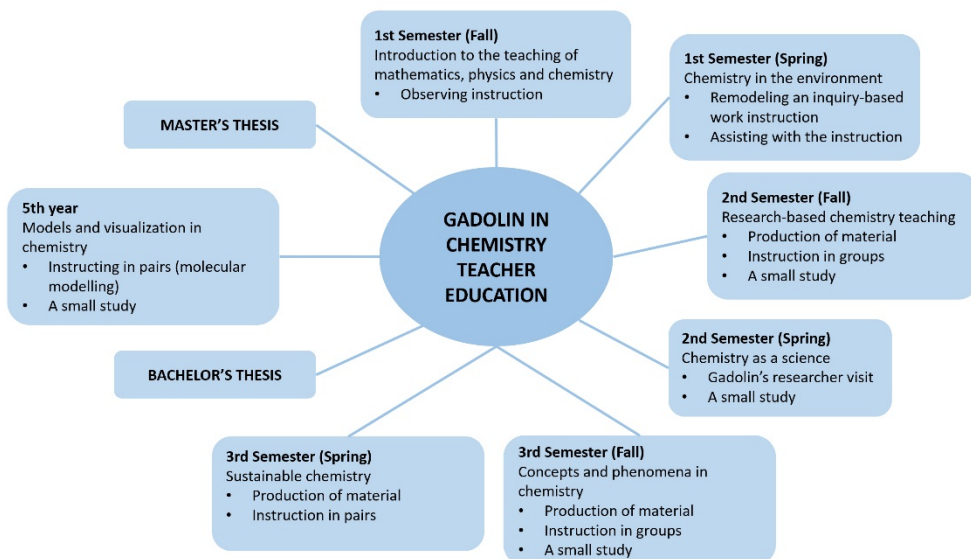


Figure 26. ChemistryLab Gadolin in courses at the Department of Chemistry at the University of Helsinki on the teaching of chemistry for future chemistry teachers.

ChemistryLab Gadolin enables the implementation of versatile assignments in courses concerning the teaching of chemistry. These assignments may for example be:

- **reflecting assignments**, in which a phenomenon is observed that is connected to a theory concerning the teaching of chemistry and its perspectives in practical implementation are pondered
- **researching assignments**, where a small case study is conducted on the basis of a theory
- **assistance assignments**, where solutions needed in inquiry are prepared or help is given in preparing modern technology

- **instructing assignments**, where a hands-on study visit is instructed partly or entirely

Using Gadolin in teacher education makes it possible to support teachers as they gradually grow into researching teachers. During the first year of their studies, future chemistry teachers get to know Gadolin's activities by observing instruction and by helping out. During the second year of their studies, they first instruct a small part of a visit and then gradually they are able to be in charge of entire visits. As a future teacher instructs children and youth that visit the Gadolin and as they have discussions with teachers of teaching groups, the future teacher learns chemistry, acquires versatile skills and is inspired to study to become a teacher and is also inspired about the future career. Gadolin instructings are usually the most liked assignments in courses concerning the teaching of chemistry.

Future chemistry teachers' comments on the significance of ChemistryLab Gadolin in courses:

"During a Gadolin instruction it was possible to observe how planned inquiry-based work would work in practice, where the mistakes would be kept in mind and they could be of for the future. The teacher's feedback and peer feedback gave tips for how to move forward."

"With the help of assignments concerning the Gadolin visit, a small case study would enlighten quite well the successfulness of the teaching and understanding of the message. It offered a lot to be developed and ideas for how to develop."

"Gadolin instruction is a good way of getting the hang of teaching inquiry."

A good example of a new opening of science education that is connected to the University's pre-service education, is the course *Chemistry as a science* that is connected to the pre-service education of chemistry teachers. A part of this course has been combined with a course of science education in chemistry, *Chemistry of health and wellbeing*. Upper secondary level students, future teachers and young researchers work in collaboration and learn from each other.



Figure 27. Future subject teacher is instructing students at ChemistryLab Gadolin. By teaching, it is possible to learn chemistry and meaningful pedagogical implementations. (Picture: Veikko Somerpuro)

4.3 Collaborative Models in Teachers' In-Service Education

ChemistryLab Gadolin in collaboration with the personnel of the Unit of Chemistry Teacher Education and with doctoral students has organized in-service education for teachers since the beginning of its operations (see [Table 5](#)). These have been for example education sessions for teachers on different levels that last for an afternoon or the entire day, workshops in national in-service education events (e.g. EDUCA fair) or participating in the project operations of the LUMA Centre (e.g. COMBLAB³¹ (Tolvanen, [2016](#)) or LINKS³²). The **themes for the educations** have mainly concerned the exploiting of inquiry in chemistry teaching. Popular topics have been ICT as support for inquiry, chemistry of cosmetics and molecular gastronomy. As the curriculum was renewed in 2015, teachers wished for training concerning the using of IR spectroscopy, because the contents of the second upper secondary level chemistry course included information about methods of analysis.

The national chemistry teaching days in 2009–2015, the annual LUMA Days and MAOL ry's Day as well as Chemistry teaching seminars in the Chemistry Days, have been the most important ongoing events that ChemistryLab Gadolin has participated in. During the Chemistry teaching days that have been organized for the past 10

³¹ suomi.luma.fi

³² luma.fi/keskus/hankkeet/links

years, ChemistryLab Gadolin in collaboration with the personnel of the Unit of Chemistry Teacher Education and with postgraduate students, has participated in addition to the workshops also in the planning of the event, in the organizing of the event and in writing a book of the Days. Articles have been aimed at being written about the operations of Gadolin and of the research conducted in the science lab, alongside published compilations of the Days.³³

Also, the study visits themselves offer in-service education for the visiting teacher. It is an entirely new kind of a model for in-service training, where the teacher can take their time and observe and reflect on the learning of children and youth through innovative activities, while the future teachers are instructing. The visiting teacher also learns, while having conversations with future teachers and the future teacher learns from the teacher.

In-service education is organized usually according to the principles of collaborative learning. The course *Inquiry and integration* from 2016–2017 is a good example of this. The aim of the course was to support and inspire future teachers, and also chemistry teachers already working in the field towards meaningful implementation of inquiry in school teaching. Students studying to be subject teachers in chemistry were the instructors for the course. The participants were kindergarten, class and subject teachers working on the field. During the course, students and teachers planned and carried out new inquiry-based work on interesting themes such as electrochemistry, colorimetry, sustainable chemistry, tasty chemistry and pretty chemistry.

Table 5. Some examples of in-service education operations from 2008-2017 that were organized in collaboration with ChemistryLab Gadolin and the Unit of Chemistry Teacher Education.

Activity	Description
New hands-on and inquiry-based work into teaching	In education, new practice works were developed according to the teacher's needs and on the basis of feedback for the use of teachers and science labs. The participating teachers take part in brainstorming the activities.
The course <i>Inquiry and integration</i>	A collaborative course for teachers on the field and for future chemistry teachers. Future subject teachers act as instructors for the course.
Formative evaluation in the teaching of natural sciences	In-service education organized by the Unit of Chemistry Teacher Education, where teachers come together to learn new information on theory, and different methods for formative evaluation are also looked at. During the meeting times a method is chosen, which is then tested in the teacher's own school, previously tested results are reported, and the evaluation method is further developed.
LINKS EU project	In the LINKS project (Learning from Innovation and Networking in STEM – science, technology, engineering and mathematics), inquiry-based teaching of LUMA subjects is promoted by developing LUMA subjects in the primary and lower secondary level as well as the lifelong learning of teachers on the upper secondary level and teacher educators of LUMA subjects.

³³ Proceedings of the National Chemistry Education days: helsinki.fi/fi/tiedekasvatus/kemian-opetuksen-paivien-kirjatverkkojulkaisut

Participation in the LUMA FINLAND program	A project that has been funded by the Ministry of Education and Culture, which has been coordinated by the LUMA Centre Finland network. This strengthens the know-how of LUMA subjects and learning in early childhood education and on the primary and lower secondary level. ChemistryLab Gadolin is a part of four chemistry projects: Everyday life phenomena, Good question!, Mathematics and natural sciences in society: collaborative learning with the Industry, and Research and ponder: preschoolers' researching skills.
10 trainings in the project: The meaningful pedagogical using of technology in hands-on teaching of LUMA subjects	In-service education project of the LUMA Centre Funded by the Finnish National Agency for Education
COMBLAB EU project	An EU funded collaborative project for developing the use of information and communications technology in the inquiry-based teaching of natural sciences, during which new inquiry-based work was developed.
Workshops for teachers	Workshops on themes such as everyday chemistry, IR spectroscopy, molecular gastronomy, molecular modelling and chemistry of cosmetics.
Chemistry 2011 main event in Narinkkatori	Workshops
LUMA science and technology seminar	Workshops
ChemBio fair	In collaboration with the Department of Chemistry
World Water Day in Heureka	Workshops
The course <i>Modern technology in support of chemistry teaching</i>	Finnish National Agency for Education's funding for in-service education
Inquiry clinic for teachers	Once a month during the spring time
The course <i>Researching chemistry teacher</i>	An in-service education course, worth 5 ECTS, Finnish National Agency for Education's funding for in-service education
EDUCA fair MAOL ry's Days LUMA Days Chemistry today event	Continuous representation either individually or with a cooperation partner. Participation could have included for example lectures, fun facts, workshops or units.
The national chemistry teaching days	Annual workshops, active membership of the organizing committee and several articles in a compilation of the days.

4.4 Operations as a Research and Development Centre

Research on chemistry education that is conducted in collaboration with ChemistryLab Gadolin and the Unit of Chemistry Teacher Education can be divided into three main categories:

1. **Research on ChemistryLab Gadolin and on processes connected to it and interactional interfaces.** The aim of this research area is to gain more information on the possibilities and challenges of non-formal learning environments, on the basis of which it is possible to develop subject teacher education, Gadolin itself and similar learning environments (see [Chapter 4.4.1](#) in more detail).
2. **Research on phenomena concerning the teaching of chemistry and approaches from the viewpoint of different theories and contexts.** Researched approaches include e.g. inquiry-based work, molecular modelling and project learning and phenomena e.g. attitudes, interest, learning motivation and the relevance of approaches in the teaching of chemistry (see [Chapter 4.4.2](#) in more detail).
3. **The research-based development of pedagogical innovations and learning materials connected to them.** ChemistryLab Gadolin makes annually new opening e.g. among themes concerning inquiry-based work. New learning material that supports inquiry-based work is developed based on research with the help of design-based research. The effectiveness of developed material in the light of various theories is researched alongside the study visits to ChemistryLab Gadolin. Developed material is published for teachers to use freely in their teaching. Development projects for new learning material are usually Master's Theses, of which tens have been made in contact with Gadolin. New theme openings from past years have been for example fuel cells, nano-chemistry and medicinal balm works (see [Chapter 4.4.3](#) in more detail).

Since Fall 2018, the role of ChemistryLab Gadolin as a research centre for the teaching of chemistry will be strengthened further. All study visits are carried out according to the Gadolin's new focus areas, and these focus areas have been derived from the thematic focus areas of the University of Helsinki's Science Education Centre. Research data is collected from all visits. Data is used in theses and in research in the Unit of Chemistry Teacher Education at the University of Helsinki. Gadolin's renewed focus areas are everyday chemistry, modern technology, and sustainable chemistry and development.

The instructors for hands-on study visits are recruited depending on whether they are completing their Bachelor's or Master's Thesis. **Research groups** are formed of instructors and researchers of the Unit of Chemistry Teacher Education according to the focus areas. The operations of the research groups are being coordinated by postgraduate students of the Unit of Chemistry Teacher Education and they are being directed by the Director of ChemistryLab Gadolin Maija Aksela and University Lecturer Johannes Pernaa in collaboration. Research is conducted in strong collaboration with Gadolin's sponsoring companies, the University of Helsinki's Department of Chemistry and educational institutions (see [Figure 28](#)).

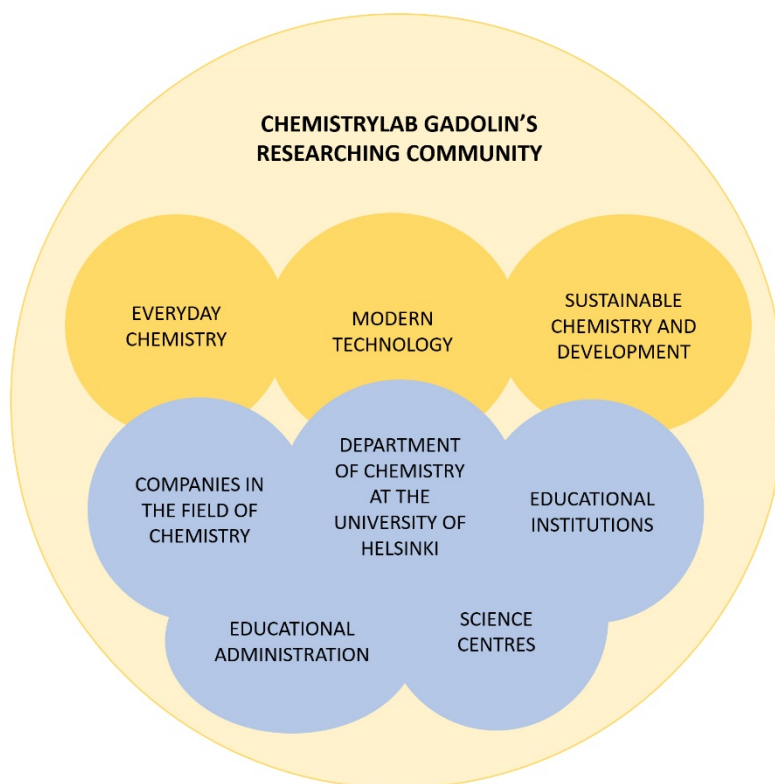


Figure 28. ChemistryLab Gadolin's researching community consists of thematic research groups that function in strong collaboration for example with companies in the field of chemistry, the Department of Chemistry, educational institutions, the Finnish National Agency for Education and with science centres.

4.4.1 Research on ChemistryLab Gadolin as a Learning Environment

ChemistryLab Gadolin as a non-formal learning environment has been researched since its year of foundation. In the research of Aksela & Pernaa (2009), teachers' needs and experience about the using of a new non-formal learning environment was found out. It was figured out in the research, how Gadolin's operations support for example the promotion of inquiry. Teachers exploited Gadolin's high-quality laboratory in such works that their school didn't have the proper equipment for. The teachers thought that Gadolin's strength lies in the fact that students got to do inquiry-based work themselves, instead of only observing e.g. demonstrations and lectures. This was experienced as a thing that motivates students, and it was thought that the University is an interesting place to visit. An authentic learning environment also fascinates students. (Aksela & Pernaa, 2009)

Teachers' answers in the research of Aksela & Pernaa (2009):

"It looks like an authentic laboratory and all the reagents were laid out. The students did not need to look for them."

"Chromatography, spectroscopy and molecular modelling are topics that we are unable to carry out in our school, and therefore they are perfect themes for visits. I think that the students got a fairly good picture of the abovementioned topics."

"The students have the possibility of working in an authentic laboratory that contains suitable equipment."

ChemistryLab Gadolin's Coordinator (2012–2016) Ph.D Veli-Matti Ikävalko researched in a doctoral thesis that he conducted for the Unit of Chemistry Teacher Education, the relevance of ChemistryLab Gadolin's learning environment, development of corporate collaboration and the didactic nature of hands-on study visits. According to the thesis, it is important in the planning of hands-on study visits to take into consideration the operations that support learning that take place before and after a study visit, such as approaches and evaluation. The study visit itself is just a part of an entity. Corporate collaboration brought significant additional value for the development of relevant inquiry-based work instructions. New, relevant inquiry-based works into the teaching of chemistry were produced through design-based research in corporate collaboration, for example: *What lays in water for household consumption?*, *Too flexible plastic* and *A problem at the pulp factory* (see [Chapter 5.2](#) for more information). (Ikävalko, 2017)



Figure 29. Also, in the course Sustainable chemistry, an inquiry-based work is designed for ChemistryLab Gadolin.

The relevance of non-formal learning environments and supporting the growing up of teachers have been the subjects of research. For example Aksela (2017a) discovered the ways in which future chemistry teachers experienced working in ChemistryLab Gadolin as relevant. According to the conducted research, instructing is thought of as relevant on each level of relevance (individual, vocational and societal),

but especially the vocational dimension was emphasized. Instructing was thought of strengthening the know-how of chemistry and of giving information, skills and self-confidence for exploiting inquiry in the future teaching career.

ChemistryLab Gadolin's Coordinator (since 2017 and onwards) Pipsa Blomgren (2018) charted visiting students' and teachers' attitudes towards the relevance of non-formal learning environments, the subject of research was visits at ChemistryLab Gadolin. **In both students' and teachers' attitudes, the levels of individual and societal relevance were especially emphasized.** It was discovered in the research that gender did not have an effect on the experienced relevance in this context, but prior interest towards chemistry on the other hand did. The students that liked chemistry as a subject already beforehand, experienced ChemistryLab Gadolin as extremely relevant. (Blomgren, 2018)

Relevance research concerning non-formal learning environments that is carried out in ChemistryLab Gadolin is published in international scientific magazines, where results and ideas become a part of broader scientific discussion on the topic. Research has a great significance in supporting the development of non-formal learning environments around the world. (Tolppanen, Vartiainen, Ikävalko, & Aksela, 2015) The results of the research are taken into consideration in the development of ChemistryLab Gadolin as a learning environment.

4.4.2 Research on Phenomena and Approaches

Researching approaches and phenomena is a part of basic research of chemistry teaching, which gives us information e.g. on learning about researched phenomena or on possibilities and challenges of approaches. Research information can be exploited e.g. in planning learning materials and education. Researches of a research category exploit especially from ChemistryLab Gadolin's substantial annual visitor amounts. Thousands of respondents enable both quantitative and qualitative collection of data efficiently and cost-effectively.

For example, in Spring 2018 Gadolin enabled an efficient collection of data for a thesis, where **lower secondary level students' experiences on the relevance of computer-assisted molecular modelling after the first modelling time**, was researched. Data has been exploited in M.Sc. Oona Kiviluoto's Master's Thesis. (Kiviluoto, 2018) A scientific paper is going to be written based on it.

According to Kiviluoto's research, mostly the societal dimension of the relevance theory was emphasized during the first round of modelling. Also, prior interest towards chemistry had an effect on the experienced relevance: students that had experienced chemistry as interesting already earlier, experienced molecular modelling as relevant especially on the individual level. Interest towards computers and technology did not have an effect on the relevance.

Another example of research belonging to this category is a Master's thesis (Heiskanen, 2016), where **learning material on inquiry-based chemistry that supports researching skills in the context of spectrophotometry**, was

developed. With this research, new information was acquired concerning what kind of a learning material supports the development of researching skills. According to Heiskanen, typical with teaching that develops researching skills is students' active participation in conducting own research, social interaction and asking questions. Workshops that develop researching skills include: choosing a research topic, asking questions, conducting research and working in a group.

4.4.3 Design-Based Research as a Tool: Development of New Solutions and Pedagogical Innovations

The development of chemistry learning materials that support the inquiry-based and research-based learning that is carried out alongside ChemistryLab Gadolin, is an area of research that is well suitable for Bachelor's and Master's Theses.³⁴ **Design-based research** is used as the method for research-based development (see [Chapter 1](#)). It is a development strategy that enables the integration of previous research information and practical experience in making development decisions. Development is carried out collaboratively and by doing this, teachers on the field and other cooperation partners can be included in the planning of learning environments. This supports the spreading out of developed solutions into schools and other learning environments.

A current example of a Master's Thesis that was made in Gadolin using design-based research is M.Sc. Tanja Luostari's (2018) thesis, where she developed a **work concerning clinical balms that supports the teaching of inquiry-based chemistry**. According to the research, Gadolin enabled a laboratory environment for the development of works and for the evaluation of the works' effectiveness. Visiting groups tested the developed works and gave feedback on them. With the help of feedback, works were developed and at the same time upper secondary level students' attitudes towards relevance concerning the context of clinical balms was researched.

Design-based research is suitable as the method for a Master's Thesis also, because usually in addition to the thesis, basic research information and a scientific paper are produced. This process increases the skills of a researcher and gives self-confidence, which then lowers the threshold for in-service education. It also supports the development of learning materials in chemistry in school work in the future.

For example, M.Sc. Matleena Boström (nee Ojapalo) developed inquiry-based work instructions for the context of fuel cells in her Master's Thesis. These instructions were tested with visiting student groups at the ChemistryLab Gadolin. The Master's Thesis was completed in 2010, after which a scientific paper on the basis of the thesis was written. The scientific article was published in 2012. (Aksela & Boström, 2012)

³⁴ The Unit of Chemistry Teacher Education, master's thesis: blogs.helsinki.fi/kem-ope/tutkimus/julkaisut/pro-gradu-tutkielmat

5 CHEMISTRYLAB GADOLIN'S MODELS FOR CORPORATE COLLABORATION

Active corporate collaboration is a part of ChemistryLab Gadolin's collaborative operating model. **Children and youth's individual, vocational and societal relevance of chemistry learning is being supported in collaboration with companies through new openings** (see the aims of the operations in [Chapter 3.1](#)). This chapter introduces successful models for corporate collaboration and research.

5.1 General Information

ChemistryLab Gadolin aims at collaborating with companies in a versatile way according to the aims and needs of chemistry teaching and companies, by exploiting most novel research information in a meaningful, pedagogical way. **The forms of collaboration are agreed upon with each company every three years, and a collaboration contract is comprised.** The agreed forms of collaboration have been collected in [Table 6](#). In addition to expertise, the company can support the promotion of science education in chemistry by donating equipment and materials for educational purposes for the science lab. For example, a cooperation partner Oy Aga Ab has donated gases for promoting inquiry-based work and for supporting the learning of gases in chemistry.

The development of relevant forms of collaboration is promoted collaboratively through work in steering groups or development work groups. From each of the collaborative companies, there is a representative in the steering group and in addition a representative appointed by the company, who then works in close collaboration with the coordinator of ChemistryLab Gadolin. Since Fall 2018, the development collaboration of new openings is tightened through a new development work group (see [Appendix 1](#)), where more new and meaningful solutions and pedagogical innovations are developed into the teaching of central focus areas including everyday chemistry, sustainable chemistry and development as well as modern technology.

5.2 Models for Corporate Collaboration

Versatile collaboration occurs with ChemistryLab Gadolin's collaborative companies (13 in total) on all levels of relevance (see [Table 6](#)): **individual, vocational and societal** (see the description of relevance theory in [Chapter 3.1](#)). Most collaborative companies are international impactors, and therefore also internationality brings additional value to the collaboration.

Table 6. ChemistryLab Gadolin's forms of corporate collaboration and the dimension of the relevance theory.

Collaboration model	A description of collaboration	Dimension of the relevance theory
Participating in the operations of the steering group or the development work group	The planning of operations of ChemistryLab Gadolin, participating in the evaluation of the operations and participating in theses as a specialist.	Vocational Individual Societal
Working life gallery	Making videos of different possibilities and career choices in the field of chemistry	Vocational Individual Societal
Collaborative works for the student laboratory and molecular modelling	Brainstorming new working instructions and development work in collaboration.	Vocational Individual Societal
Collaborative events	For example, collaborative workshops in different events, workshops in the cooperation partner's family events etc.	Vocational Individual Societal
Visits of company personnel to ChemistryLab Gadolin	Getting to know the activities of ChemistryLab Gadolin, developing the operations and educating instructors.	Vocational Individual
Visits of ChemistryLab Gadolin's instructors to collaborative companies	The instructors of ChemistryLab Gadolin have often visited collaboration companies to get to know their operations, in order to develop their own expertise and to be able to tell about their operations as best as they can to the makers of the future.	Vocational Individual
Company-based exhibit space in ChemistryLab Gadolin	Companies get their own exhibit space, company showcases, among Gadolin, where they can include information about their company and its products.	Societal

ChemistryLab Gadolin's corporate collaboration is developed on the basis of research. Phenomena and questions connected to it are aimed at being understood more deeply through the **STSE theory (science, technology, society, environment)**. The entity of science, technology, society and environment of chemistry and the interactional relationship between these is researched and at the same time, ways are developed on how to exploit the STSE theory even better in chemistry teaching. According to research, teaching that is based on the STSE theory supports especially the growth of a student's feeling of individual and societal relevance. However, teachers do not integrate the STSE thinking enough into their teaching. New approaches concerning the topic are needed in teacher's pre-service and in-service education (Kousa, Aksela & Ferk Savec, submitted).

In the University of Helsinki's science education, a new kind of a model for teacher's pre-service and in-service education has been developed based on research

in the course *Mathematics and natural sciences in society*, and an online course is about to be finished in promotion of school corporate collaboration as a part of LUMA Finland development program.³⁵ Themes have included a central theme from the focus areas of science education in chemistry, mainly the theme sustainable chemistry and development, and more specific themes such as circulatory economy and water.



Figure 30. An example of collaboration between the company specialist and ChemistryLab Gadolin: the specialists Aila Weaver ja Minna Matrone from Oy Aga Ab tell about the operations of AGA and about the chemistry of gases to upper secondary level students and their teacher during Komppa days.

The development of relevant **inquiry-based work and other activities** is one of ChemistryLab Gadolin's central form of collaboration. In inquiry-based work that has been developed together or in molecular modelling, the company's field of chemistry is quite visible, and children and youth get a broader and more up to date picture. According to Ikävalko (2017), the authentic context of chemistry that the companies offer, raises the relevance of inquiry-based work, which then inspires students towards studying chemistry. Development work that has been carried out as corporate collaboration has been exploited also in support of chemistry teacher education, because future chemistry teachers developed works as a part of the course *Inquiry in chemistry teaching II* in 2013. Students developed first versions of works that were later further developed in Ikävalko's doctoral research (2017). In the research, a total of nine relevant inquiry-based work instructions were collaboratively developed, a compilation of these has been introduced in [Table 7](#).

³⁵ suomi.luma.fi

Work instructions that were developed by Ikävalko (2017) in corporate collaboration were made to resemble operating models that were developed as a part of the doctoral thesis. For example, the work instruction *Traces of chlorine in drinking water* that was developed in collaboration with Kemira, consists of three stages: 1) a stage that tunes in for completing the work, this consists of questions to ponder on that the teacher can give for example as homework before the hands-on study visit, 2) the guidelines of completing the work with steps during the hands-on study visit as well as questions, with which it is possible to summarize after completing the work and 3) after the hands-on study visit, the teacher can give pondering questions for the students to complete as homework that can be used as part of teaching or evaluation.

In science education at the ChemistryLab Gadolin, versatile models are developed in highlighting the **versatile possibilities of the field of chemistry and its career possibilities**. The assembling of the so-called company video gallery is one collaborative subject of development. In short videos, the company specialist tells about their education, work and about the fascination of chemistry. The contents of the videos and the implementation is performed in collaboration with the company. These videos can be used in the teaching of chemistry in schools, in student counseling or during hands-on study visits to ChemistryLab Gadolin.

One form of collaboration between ChemistryLab Gadolin and the cooperative companies is visits to companies and counter visits to ChemistryLab Gadolin. Gadolin instructors can also organize **family events in companies**. By visiting companies of the field, instructors learn new information concerning the field of chemistry and have the ability to better share information on the topic to visiting school groups.

Visits of specialists from collaborative companies to ChemistryLab Gadolin are possible, and it is also possible to get to know the possibilities that a science lab has to offer and to participate in the development of the science lab. Specialists can also organize educational days for ChemistryLab Gadolin's instructors, student teachers of chemistry, chemistry teachers and upper secondary level students interested in chemistry. It is also possible that the company holds meetings at the Department of Chemistry, and possible to get to know research in chemistry, in addition to the operations of Gadolin.

Table 7. The context-basedness, contents and technology concerning works developed in corporate collaboration (Ikävalko, 2017, pp. 97, 100)

Work	Context	Contents	Technology	Company
1. What lays in water for household consumption?	<ul style="list-style-type: none"> - Household - Environment and nature - Industry, technology and production - Human biology and health 	<ul style="list-style-type: none"> - Ions - Solution - The quality of water - Chromatography (IC) - Quantitative determining 	Ion chromatography (IC)	Metrohm Nordic Oy
2. Too flexible plastic	<ul style="list-style-type: none"> - Household - Industry, technology and production 	<ul style="list-style-type: none"> - Polymeers - Types of plastic - Spectroscopy (IR) - Quantitative determining 	Infrared spectroscopy (IR)	Borealis Polymers Oy
3. A problem at the pulp factory	<ul style="list-style-type: none"> - Industry, technology and production 	<ul style="list-style-type: none"> - Functional groups - Acids and bases - Solubility 	-	UPM-Kymmene Oyj
4. Traces of chlorine in water	<ul style="list-style-type: none"> - Household - Environment and nature - Industry, technology and production - Human biology and health 	<ul style="list-style-type: none"> - The quality of water - Spectroscopy (Vis) - Quantitative determining 	Spectroscopy (Vis)	Kemira Oyj
5. Determining the salt concentration	<ul style="list-style-type: none"> - Household - Environment and nature 	<ul style="list-style-type: none"> - Solution - Ions - Water conductivity - Quantitative determining 	Microcomputer-based laboratory	Las-kentä-väline Oy
6. Bio-diesel	<ul style="list-style-type: none"> - Household - Environment and nature - Industry, technology and production 	<ul style="list-style-type: none"> - Organic synthesis - Esterification 	Equipment for organic synthesis	Neste Oil Oyj
7. The sugar concentration of soda	<ul style="list-style-type: none"> - Household - Industry, technology and production 	<ul style="list-style-type: none"> - Solution - Quality assurance - Spectroscopy (IR) - Quantitative determining 	Infrared spectroscopy (IR)	Bruker Corporation
8. Researching E. coli bacterium	<ul style="list-style-type: none"> - Household - Environment and nature - Industry, technology and production - Human biology and health 	<ul style="list-style-type: none"> - Microbiology - Hygiene - Indicators 	A ready-made seedbed	3M Finland
9. The hardness of water	<ul style="list-style-type: none"> - Household - Environment and nature - Industry, technology and production - Human biology and health 	<ul style="list-style-type: none"> - Gases - Hardness of water - Acidity - Solubility of gases into water - Quantitative determining 	Microcomputer-based laboratory	Oy AGA Ab

AFTERWORD

ChemistryLab Gadolin's **collaborative science education** (see [Chapter 2.1](#)) offers a new kind of an inspiring learning environment for the makers of the future (children and youth), future teachers, teachers on different levels and for families as well as a development and researching environment of science education in chemistry for developing new and relevant solutions and pedagogical innovations. At the same time through the operating model, the individual, vocational and societal relevance of children and youth is promoted. By collaborating with different cooperation partners collaboratively, most novel research information and innovations in chemistry are spread in a meaningful way into use in science education of chemistry from early childhood education to universities, and together new solutions are discovered for inspiring makers of the future towards studying chemistry. **Joy of insight and success for all!**

Engaging and collaborative design-based research that is a part of the operations of ChemistryLab Gadolin, offers a perfect tool for developing new solutions and pedagogical innovations into science education in chemistry and for support of carrying out current and future curricula. At the same time, using this type of research promotes the implementation of a new kind of a collaborative model for teacher's pre-service and in-service education, where all the impactors learn from each other and they produce relevant solutions together into science education of chemistry, also internationally.



Together towards a bright future of chemistry!

REFERENCES

- Affeldt, F., Tolppanen, S., Aksela, M., & Eilks, I. (2017). The Potential of the Non-Formal Educational Sector for Supporting Chemistry Learning and Sustainability Education for All Students--A Joint Perspective from Two Cases in Finland and Germany. *Chemistry Education Research and Practice*, 18(1), 13–25.
<https://doi.org/10.1039/C6RP00212A>
- Ahonen, P.-P. (2017). Tiedekasvatus on tärkeää yhteiskunnalle - Tietysti.fi. Retrieved August 15, 2018, from <http://www.aka.fi/fi/tietysti/blogit/kuulumisia-tieteesta/tiedekasvatus-on-tarkeaa-yhteiskunnalle>
- Aksela, M. (2005). *Supporting meaningful chemistry learning and higher-order thinking through computer-assisted inquiry: A design research approach* (PhD thesis). University of Helsinki, Helsinki. Retrieved from <https://helda.helsinki.fi/handle/10138/21127>
- Aksela, M. (2010). Evidence-based teacher education: becoming a lifelong research-oriented chemistry teacher? *Chemistry Education Research and Practice*, 11(2), 84–91.
<https://doi.org/10.1039/C005350N>
- Aksela, M. (2011). Engaging students for meaningful chemistry learning through Microcomputer-based Laboratory (MBL) inquiry. *Educació química*, 0(0), 30–37.
- Aksela, M. (2012). Tiedekasvatus ja sen tulevaisuus. *Tieteessä tapahtuu*, 30(4). Retrieved from <https://journal.fi/tt/article/view/6496>
- Aksela, M. (2016). Foreword. *LUMAT-B: International Journal on Math, Science and Technology Education*, 1(3). Retrieved from <https://www.lumat.fi/index.php/lumat-b/article/view/18>
- Aksela, M. (2017a). ChemistryLab Gadolin as a Relevant Learning Environment for Lifelong Learning. In *ESERA 2017 Conference*. Dublin: ESERA. Retrieved from https://keynote.conference-services.net/resources/444/5233/pdf/ESERA2017_0751_paper.pdf
- Aksela, M. (2017b). Lasten ja nuorten tieteestä innostuminen vahvistaa Suomen hyvää tulevaisuutta. Retrieved August 15, 2018, from <http://www.aka.fi/fi/tietysti/blogit/kuulumisia-tieteesta/lasten-ja-nuorten-tieteesta-innostuminen-vahvistaa-suomen-hyvaa-tulevaisuutta>
- Aksela, M., & Boström, M. (2012). Supporting Students' Interest through Inquiry-Based Learning in the Context of Fuel Cells. *Mevlana International Journal of Education*, 2(3), 53–61.
- Aksela, M., & Ikävalko, V.-M. (2016). How to promote relevant practical work in science education through a non-formal learning environment. In I. Eilks, S. Markic, & B. Ralle (Eds.), *Science Education Research and Practical Work : A collection of invited papers inspired by the 23rd Symposium on Chemistry and Science Education held at the TU Dortmund Uni-versity*. Aachen.
- Aksela, M., & Juvonen, R. (1999). *Kemian opetus tänään*. Helsinki: National Board of education. Retrieved from https://www.oph.fi/download/49150_kemianopetus_tanaan.pdf
- Aksela, M., & Karjalainen, V. (2008). *Kemian opetus tänään: Nykytila ja haasteet Suomessa*. Helsinki: Kemian opetuksen keskus, Helsingin yliopisto. Retrieved from <http://www.kemia.ovh/ont/karjalainen-v-2008.pdf>
- Aksela, M., & Lundell, J. (2008). Computer-based molecular modelling: Finnish school teachers' experiences and views. *Chem. Educ. Res. Pract.*, 9(4), 301–308.
<https://doi.org/10.1039/B818464J>
- Aksela, M., Lundell, J., & Pernaa, J. (2008). Molekyylihallinnuksen mentoreita kemian opetuksen ja oppimisen tueksi. In J. Lundell & J. Väliäsaari (Eds.), *Kemian opetuksen päivät 2008: Uusia oppimisympäristöjä ja ongelmalähtöistä opetusta* (pp. 59–68). Jyväskylä: University of Jyväskylä.

- Aksela, M., Oikkonen, J., & Halonen, J. (Eds.). (2018). *Collaborative Science Education at the University of Helsinki: New Solutions and Pedagogical Innovations for Teaching from Early Childhood Education to Universities*. Helsinki: Helsingin yliopisto. Helsinki: University of Helsinki. Retrieved from <https://www.helsinki.fi/sites/default/files/atoms/files/isbn-978-951-51-4089-0.pdf>
- Aksela, M., & Pernaa, J. (2009). Kemianluokka Gadolin -opettajien kokemuksia uuden oppimisympäristön käytöstä. In M. Aksela & J. Pernaa (Eds.), *Arkipäivän kemia, kokeellisuus ja työturvallisuus kemian opetuksessa perusopetuksesta korkeakouluhin – IV Valtakunnalliset kemian opetuksen päivät* (pp. 40–49). Helsinki: University of Helsinki.
- Aksela, M., Pernaa, J., & Hopea-Manner, A. (julkaisu valmistumassa). *Kemian opetus tänään 2018*. Helsinki: Helsingin yliopisto.
- Aksela, M., Vartiainen, J., Tuomisto, M., Turkk, J., Pernaa, J., & Tolppanen, S. (2016). Promoting Meaningful Science Teaching and Learning Through ICT in the Finnish LUMA Ecosystem. In H. Niemi & J. Jia (Eds.), *New Ways to Teach and Learn in China and Finland : Crossing Boundaries with Technology*. Frankfurt am Main: Peter Lang.
- Aksela, M., Wu, X., & Halonen, J. (2016). Relevancy of the Massive Open Online Course (MOOC) about Sustainable Energy for Adolescents. *Education Sciences*, 6(4), 40. <https://doi.org/10.3390/educsci6040040>
- Blomgren, P. (2018). *Kemian non-formaalin oppimisympäristön relevanssi oppilaiden ja opettajien näkökulmista* (Master's thesis). Helsingin yliopisto, Helsinki. Retrieved from <https://blogs.helsinki.fi/kem-ope/tutkimus/julkaisut/pro-gradu-tutkielmat>
- Heiskanen, N. (2016). *Kehittämistutkimus: Tutkimisen taitojen edistäminen tutkimuksellisella spektrofotometriä oppimiskokonaisuudella lukion kemian opetuksessa* (Master's thesis). University of Helsinki, Helsinki. Retrieved from <http://urn.fi/URN:NBN:fi-fe2017112251080>
- Heiskanen, N., Käyhkö, J., & Virtanen, H. (2017). Students as teachers: A student point of view. *LUMAT-B: International Journal on Math, Science and Technology Education*, 2(3), 91–93.
- Ikävalko, V.-M. (2017). *Mielekkään kemian non-formaalin oppimisympäristön kehittämistutkimus yhteistyössä työelämän kanssa* (Academic dissertation). University of Helsinki, Helsinki. Retrieved from <https://helda.helsinki.fi/handle/10138/180559>
- Juntunen, M. (2015). *Holistic and Inquiry-Based Education for Sustainable Development in Chemistry* (Academic dissertation). University of Helsinki, Helsinki. Retrieved from <http://urn.fi/URN:ISBN:978-951-51-1312-2>
- Kaul, M., Aksela, M., & Wu, X. (2018). Dynamics of the Community of Inquiry (CoI) within a Massive Open Online Course (MOOC) for In-Service Teachers in Environmental Education. *Education Sciences*, 8(2), 40. <https://doi.org/10.3390/educsci8020040>
- Kiviluoto, O. (2018). *Tietokoneavusteisen molekyylihallinnuksen relevanssi 7.–9. luokilla oppilaan ensikokemuksen näkökulmasta* (Master's thesis). University of Helsinki, Helsinki. Retrieved from <https://blogs.helsinki.fi/kem-ope/tutkimus/julkaisut/pro-gradu-tutkielmat>
- Luostari, T. (2018). *Kehittämistutkimus: Relevantti tutkimuksellinen ja kokeellinen opiskelu lääkekemian kontekstissa* (Master's thesis). Helsingin yliopisto, Helsinki. Retrieved from <http://urn.fi/URN:NBN:fi:hulib-201804131666>
- Pernaa, J. (2011). *Kehittämistutkimus: Tieto- ja viestintätekniikkaa kemian opetukseen*. University of Helsinki, Helsinki. Retrieved from <https://helda.helsinki.fi/handle/10138/28007>
- Pernaa, J., Aksela, M., & Ghulam, S. P. (2017). *Introduction to Molecular Modeling in Chemistry Education* (2nd ed.). Jokioinen: e-Oppe Ltd. & Edumendo Publishing.
- Pernaa, J., Aksela, M., & Lundell, J. (2009). Kemian opettajien käsityksiä molekyylihallinnuksen käytöstä opetuksessa. In M. Aksela & J. Pernaa (Eds.), *Arkipäivän kemia, kokeellisuus ja työturvallisuus kemian opetuksessa perusopetuksesta korkeakouluhin – IV Valtakunnalliset kemian opetuksen päivät* (pp. 195–204). Helsinki: University of Helsinki.

- Stuckey, M., Hofstein, A., Mamlok-Naaman, R., & Eilks, I. (2013). The meaning of 'relevance' in science education and its implications for the science curriculum. *Studies in Science Education*, 49(1), 1–34. <https://doi.org/10.1080/03057267.2013.802463>
- Tolppanen, S. (2015). *Creating a Better World : Questions, Actions and Expectations of International Students on Sustainable Development and Its Education* (Academic dissertation). University of Helsinki, Helsinki. Retrieved from <http://urn.fi/URN:ISBN:978-951-51-1312-2>
- Tolppanen, S., Vartiainen, J., Ikävalko, V.-M., & Aksela, M. (2015). Relevance of Non-Formal Education in Science Education. In I. Eilks & A. Hofstein (Eds.), *Relevant Chemistry Education: From Theory to Practice* (pp. 335–354). Rotterdam: SensePublishers. https://doi.org/10.1007/978-94-6300-175-5_18
- Tolvanen, S. (2016). Microcomputer-based laboratory (MBL) in chemistry teaching. *LUMAT-B: International Journal on Math, Science and Technology Education*, 1(3). Retrieved from <https://www.lumat.fi/index.php/lumat-b/article/view/22>
- Tolvanen, S., & Aksela, M. (2013). Utilizing microcomputer-based laboratory in inquiry-based chemistry learning. *LUMAT (2013–2015 Issues)*, 1(4), 379–386.
- Tolvanen, S., Aksela, M., Guitart, F., & Urban-Woldron, H. (2014). Research-based future science teacher training on using ICT- enhanced inquiry activities. In G. Olympiou & P. Marzin-Janvier (Eds.), *E-Book Proceedings of the ESERA 2013 Conference : Science Education Research For Evidence-based Teaching and Coherence in Learning* (pp. 181–190). Nicosia, Kypros: European Science Education Research Association.

APPENDICES

Appendix 1. The Collaborative Gadolin Team

The operations of the science lab ChemistryLab Gadolin is an example of collaborative cooperation between various partners. During the last ten years, tens of people and in addition numerous future teachers have participated in the operations. **Together we are more!** (LUMA motto)

Contact details and the location: ChemistryLab Gadolin is located in Helsinki at the Kumpula science campus in the first floor of the building Chemicum (A. I. Virtasen aukio 1).

www.kemianluokka.fi / kemianluokkagadolin@helsinki.fi

1. Director and the Vice Director

The director of the science lab ChemistryLab Gadolin and the "mother" of the idea for the operating model has been since the beginning of operations, Professor, Ph.D **Maija Aksela** (the Director of LUMA Centre Finland, the Director of Science Education Centre at the University of Helsinki and the Director of the Unit of Chemistry Teacher Education). ChemistryLab Gadolin's Coordinators and Vice Coordinators (see a table of the names below) operate under her instruction. She has been responsible for research concerning the lab, financing and collaboration contracts.

maija.aksela@helsinki.fi / +358 50 514 1450

Since 2017, Ph.D Johannes Pernaa from the Unit of Chemistry Teacher Education at the Department of Chemistry has been the **Vice Director**. Currently he is a member of **Gadolin's executive group** and he participates in instructing the coordinator and vice coordinator, in developing teacher education concerning the operations of Gadolin and in observing research and financing. Johannes Pernaa has been a part of Gadolin's operations since the beginning (see e.g. Aksela & Pernaa, 2009).

johannes.bernaa@helsinki.fi / +358 50 348 0567

2. The steering group and the development work group

The steering group (2008–2018) has had a significant role in the brainstorming, developing and evaluating of the operations as well as in its directing and taking care of the finances. The steering group that consists of representatives of ChemistryLab Gadolin's cooperation partners (see [Appendix 2](#)) has had two meetings each year, during the operating years. Each year, annual reports have been comprised concerning the operations and these reports have been published online.³⁶

Since Fall 2018, the steering group will carry on with the name **ChemistryLab Gadolin's development work group** (see names below).

Members of the steering group (2008–2018):

Chairperson

Professor Mikko Ritala, Department of Chemistry, Faculty of Science, University of Helsinki (as a recognition for his significant work, he has been awarded with the Gadolin Ambassador recognition).

The following people have acted as **secretaries** during different periods of time:

- Coordinator Maria Vänskä, Department of Chemistry, Faculty of Science, University of Helsinki (2008–2009)
- Coordinator Greta Tikkanen, Department of Chemistry, Faculty of Science, University of Helsinki (2009–2010)
- Coordinator Marja Happonen, Department of Chemistry, Faculty of Science, University of Helsinki (2010–2012)
- Coordinator Veli-Matti Ikävalko, Department of Chemistry, Faculty of Science, University of Helsinki (2012–2016)
- Coordinator Tanja Luostari, Department of Chemistry, Faculty of Science, University of Helsinki (2016–2017)
- Coordinator Pipsa Blomgren, Department of Chemistry, Faculty of Science, University of Helsinki (2017–2018).

The following people **have been members** of the steering group:

- Professor Markku Räsänen, Department of Chemistry, Faculty of Science, University of Helsinki

³⁶ <https://www.helsinki.fi/fi/tiedekasvatus/keskus/toimintakertomukset>

- the Director of ChemistryLab Gadolin, professor Maija Aksela, Department of Chemistry, Faculty of Science, University of Helsinki
- Professor Heikki Tenhu, Department of Chemistry, Faculty of Science, University of Helsinki
- Professor Jari Yli-Kauhaluoma, Faculty of Pharmacy, University of Helsinki
- Councillor for Education Marja Montonen, Finnish National Agency for Education
- Councillor for Education Teijo Koljonen, Finnish National Agency for Education
- Director General Timo Leppä, Chemical Industry Federation of Finland
- Senior Advisor Riitta Juvonen, Chemical Industry Federation of Finland
- Specialist Anni Siltanen, Chemical Industry Federation of Finland
- Director Carmela Kantor-Aaltonen, Finnish Bioindustries
- Director Ilkka Pollari, Kemira Oyj
- Research Scientist Katja Nemtsinkoff, Kemira Oyj
- Senior Associate Alpo Toivo, Neste Oil Oyj
- HR Manager Mika Talvio, AGA Oy
- Manager, HR Services, Marja Ora, Borealis Polymers Oy
- the Vice Director of ChemistryLab Gadolin Johannes Perna, Department of Chemistry, Faculty of Science, University of Helsinki
- Country Manager, laboratory equipment, Salla Paajanen, Metrohm Nordic Oy
- Sales Manager Jukka Kivelä, Thermo Fischer Scientific Oy
- Education Consultant Leena Hiillos, City of Helsinki
- Education Consultant Kirsi Verkka, City of Helsinki
- Stakeholder Relations Pirkko Harrela, UPM-Kymmene Oyj
- Production Manager Kari Sarantila, Borealis Polymers Oy
- Communications Manager Iris Ponkala-Kauppila, BASF Oy
- University Lecturer Jarkko Lampiselkä, Faculty of Educational Sciences, University of Helsinki
- Finnish Commercial Manager Inka Ylipietä, Nordic Channel Manager, 3M Medical Business
- Executive Manager Juha Sola, MAOL ry (a union for teachers of mathematical subjects)

- Executive Manager Heleena Karrus, Finnish Chemical Society, the unit of chemistry education
- Product Manager Lauri Stark, MAOL ry
- Researcher Kaisa Karisalmi, Kemira Espoo Research Center
- T3 Educator, Markku Parkkonen, Laskentaväline
- Project Manager Minna Matrone, Oy AGA Ab
- Chairperson Nina Aremo, Finnish Chemical Society, the unit of chemistry education
- Vice Coordinator Antti Pohjola, Department of Chemistry, Faculty of Science, University of Helsinki
- Vice Coordinator Heidi Venho, Department of Chemistry, Faculty of Science, University of Helsinki
- Area HR Manager Tiina Paulamäki, Borealis Polymers Oy
- Sales and Applications Engineer Timo Saarela, Bruker Optics Scandinavia.

3. Development work group (Fall 2018–):

The development work group continues the successful operations of the steering group. The emphasis is on the brainstorming of new opening and practical implementation in collaboration in the context of three main themes: **(i) everyday chemistry, (ii) sustainable chemistry and development and (iii) modern technology**. The work group meets at least two times each year.

Chairperson: Director of ChemistryLab Gadolin, Professor **Maija Aksela**, Department of Chemistry, Faculty of Science, University of Helsinki

Vice Chairperson: Vice Director of ChemistryLab Gadolin, University Lecturer **Johannes Pernaa**, Department of Chemistry, Faculty of Science, University of Helsinki

Secretaries

Coordinator **Pipsa Blomgren**, Department of Chemistry, Faculty of Science, University of Helsinki

Vice Coordinator **Iisa Rautiainen**, Department of Chemistry, Faculty of Science, University of Helsinki

The members consist of representatives of our collaborative companies.³⁷

³⁷ helsinki.fi/en/science-education/for-teachers/group-visits-to-science-labs/chemistrylab-gadolin

4. Coordinators and Vice Coordinators

Coordinators and Vice Coordinators (see the [Table](#) below) have acted as the hearts of Gadolin and as realizers in practice. Their main tasks have included organizing practical operations according to the aims and reporting under the guidance of the director, collaboration with cooperation partners, instructing **instructors** that have participated in the operations, and organizing team meetings and taking part in research. The coordinators have participated in the team of coordinators of the Science Education Centre at the University of Helsinki and participated in the tasks of science education on behalf of their expertise, since 2017.

Since 2017, the Coordinator has been **Pipsa Blomgren** and the Vice Coordinator since Fall 2018 is **Iisa Rautiainen**.

pipsa.blomgren@helsinki.fi / +358 29 415 0462
iisa.rautiainen@helsinki.fi

5. Instructors

Instructors (see the names on the [Table](#) below that have been found from annual reports) have been completing hourly work in Gadolin alongside their studies. The important task of instructors has been to instruct visitors, and plan the implementation with teachers, which has then supported the aims according to the core curriculum. They are mainly future teachers and researchers in chemistry. At the same time, the instruction work supports their growing into chemistry teachers. They have been chosen for this representing task based on applications and interviews and they also have received education for the job. In addition, many students participate in lab tasks as part of their courses in the Unit of Chemistry Teacher Education.

In addition, **doctoral students at the Unit of Chemistry Teacher Education** such as Päivi Kousa and Outi Haatainen as well as abovementioned, have actively participated in developing science education operations in chemistry.

Table. ChemistryLab Gadolin's coordinators, vice coordinators and instructors 2008-2018.

Se- mes- ter	Coordinator	Vice coordinator(s)	Instructors * (those names that were found in annual reports are included)
2008– 2009	Maria Vänskä	Johannes Pernaa	Maria Vänskä, Johannes Pernaa, Jenni Västinsalo (currently Vartiainen) and Veli-Matti Vesterinen
2009– 2010	Greta Tikkanen	Johannes Pernaa	Greta Tikkanen, Johannes Pernaa, Marja Happonen (currently Tamm) and Jenni Västinsalo (currently Vartiainen)
2010– 2011	Marja Happonen (currently Tamm)	Antti Pohjola, Johannes Pernaa	Marja Happonen, Antti Pohjola, Johannes Pernaa + 8 hired instructors
2011– 2012	Marja Happonen (currently Tamm)	Simo Tolvanen, Maiju Tuomisto	Annina Kari, Timo Jääskeläinen, Minja Lahdelma, Anna Palomäki, Ilona Linnavuori, Terhi Korhonen, Juhani Lähde and Jaakko Turkka
2012– 2013	Veli-Matti Ikävalko	-	Jane Laamanen, Annina Kari, Minja Lahdelma, Timo Jääskeläinen, Teemu Santavuori, Ilona Linnavuori, Juhani Lähde and Terhi Korhonen
2013– 2014	Veli-Matti Ikävalko	Annina Kari	Annina Kari, Timo Jääskeläinen, Jane Laamanen, Matleena Hintsala, Fanny Bergström (currently Salonen), Timo Jääskeläinen, Juhani Lähde, Terhi Korhonen and Katariina Tammi
2014– 2015	Veli-Matti Ikävalko	Jane Laamanen, Jaana Herranen	Fanny Bergström (currently Salonen), Timo Jääskeläinen, Minja Lahdelma, Tanja Luostari, Anna Palomäki, Toni Rantaniitty, Katariina Tammi, Jaakko Tuunanen, Sonja Martikainen and Heidi Venho
2015– 2016	Veli-Matti Ikävalko	Sonja Martikainen (currently Saloriutta)	Fanny Bergström (currently Salonen), Pipsa Blomgren, Julia Halonen, Timo Jääskeläinen, Jaakko Karjalainen, Tanja Luostari, Essi Purhonen, Iisa Rautiainen, Katariina Tammi, Heidi Venho and Henri Tunturi
2016– 2017	Sonja Martikainen (currently Saloriutta) ja Tanja Luostari	Heidi Venho	Pipsa Blomgren, Julia Halonen, Joona Kontinen, Essi Purhonen, Iisa Rautiainen, Henri Tunturi, Jaakko Karjalainen, Toni Silvennoinen and Noora-Kaisa Rantanen
2017– 2018	Pipsa Blomgren	-	Aukusti Koivu, Joona Kontinen, Fanny Kytölä, Vilja Kämppi, Minja Lahdelma, Terhi Närhi, Iisa Rautiainen, Laura Saarinen, Veera Sinikallio and Katariina Tammi
2018– 2019	Pipsa Blomgren	Iisa Rautiainen	Aukusti Koivu, Fanny Kytölä, Vilja Kämppi, Minja Lahdelma, Terhi Närhi, Laura Saarinen, Veera Sinikallio and Katariina Tammi

Appendix 2. Cooperation Partners and Sponsors

The following cooperation partners have participated in sponsoring ChemistryLab Gadolin in addition to science education at the University of Helsinki and the Department of Chemistry. Since the beginning, the main sponsor has been Neste Oyj. The Department of Chemistry in the Faculty of Science at the University of Helsinki has offered laboratory facilities. More national and international cooperation partners are wished to participate (see contact details in [Appendix 1](#)).

Together we are more! (LUMA-motto)

Table. Cooperation partners and sponsors.

Term	Sponsors/funders	Equipment and product support	Other cooperation partners
2008— 2011	Main sponsors: Kemira Oyj Neste Oil Oyj In addition, operations were sponsored by: BASF Oy Borealis Polymers Oy Bruker Corporation Danisco Oy Chemical Industry Federation of Finland Department of Chemistry at the University of Helsinki Kemira Oyj OMG Kokkola Chemicals Oy Oy AGA Ab	Is-Vet Oy Laskentaväline Bruker Corporation VWR International Oy PLD Finland Oy BASF Oy Metrohm Nordic Oy PLD Finland Oy Finland's 3M Oy Thermo Fisher Scientific Oy VWR International Oy	City of Helsinki, Local education department Finnish National Agency for Education Finnish Chemical Society, The Unit of Chemistry Education MAOL ry Kemma Centre for Chemistry Education the Faculty of Pharmacy, University of Helsinki National LUMA Centre Schools and educational institutions Finnish Bioindustries FIB
2011— 2012	Main sponsors: Kemira Oyj Neste Oil Oyj In addition, operations were sponsored by: BASF Oy Borealis Polymers Oy Bruker Corporation Danisco Oy Chemical Industry Federation of Finland Department of Chemistry at the University of Helsinki UPM-Kymmene Oyj Oy AGA Ab	Epicur Group Oy Is-Vet Oy Laskentaväline VWR International Oy PLD Finland Oy Metrohm Nordic Oy Finland's 3M Oy Thermo Fisher Scientific Oy	City of Helsinki, Local education department Finnish National Agency for Education Finnish Chemical Society, The Unit of Chemistry Education MAOL ry Kemma Centre for Chemistry Education the Faculty of Pharmacy, University of Helsinki National LUMA Centre Schools and educational institutions Finnish Bioindustries FIB
2012— 2013	Main sponsors: Kemira Oyj Neste Oil Oyj In addition, operations were sponsored by: AGA Oy BASF Borealis Polymers Oy Bruker Corporation Chemical Industry Federation of Finland	Epicur Group Oy Is-Vet Oy Laskentaväline Bruker Corporation VWR International Oy PLD Finland Oy Metrohm Nordic Oy Finland's 3M Oy Thermo Fisher Scientific Oy	City of Helsinki, Local education department Finnish National Agency for Education Finnish Chemical Society, The Unit of Chemistry Education MAOL ry Kemma Centre for Chemistry Education the Faculty of Pharmacy, University of Helsinki

	Department of Chemistry at the University of Helsinki UPM-Kymmene Oyj BASF Oy		National LUMA Centre Schools and educational institutions Finnish Bioindustries FIB
2013— 2014	Main sponsors: Kemira Oyj Neste Oil Oyj UPM-Kymmene Oyj In addition, operations were sponsored by: Oy AGA Ab BASF Oy Borealis Polymers Oy Bruker Corporation Chemical Industry Federation of Finland	Epicur Group Oy IS-Vet Oy Laskentaväline Oy Metrohm Nordic Oy Miliot Science PLD Finland Oy Finland's 3M Oy Thermo Fisher Scientific Oy VWR International Oy	City of Helsinki, Local education department Finnish National Agency for Education Finnish Chemical Society, The Unit of Chemistry Education MAOL ry Kemma Centre for Chemistry Education the Faculty of Pharmacy, University of Helsinki National LUMA Centre Schools and educational institutions Finnish Bioindustries FIB
2014— 2015	Main sponsors: Kemira Oyj Neste Oil Oyj UPM-Kymmene Oyj In addition, operations were sponsored by: BASF Oy Borealis Polymers Oy Bruker Corporation Chemical Industry Federation of Finland Oy AGA Ab	IS-Vet Oy Laskentaväline Oy Metrohm Nordic Oy Miliot Science PLD Finland Oy Finland's 3M Oy Thermo Fisher Scientific Oy VWR International Oy	City of Helsinki, Local education department Finnish National Agency for Education Finnish Chemical Society, The Unit of Chemistry Education MAOL ry Kemma Centre for Chemistry Education the Faculty of Pharmacy, University of Helsinki National LUMA Centre Schools and educational institutions
2015— 2016	Main sponsors: Kemira Oyj Neste Oyj UPM-Kymmene Oyj In addition, operations were sponsored by: BASF Oy Borealis Polymers Oy Bruker Corporation Chemical Industry Federation of Finland Oy AGA Ab	IS-Vet Oy Laskentaväline Oy Metrohm Nordic Oy Miliot Science Suomen 3M Oy Thermo Fisher Scientific Oy VWR International Oy	City of Helsinki, Local education department Finnish Chemical Magazine MAOL Finnish National Agency for Education Finnish Chemical Society, The Unit of Chemistry Education Finnish Bioindustries FIB Kemma Centre for Chemistry Education the Faculty of Pharmacy, University of Helsinki National LUMA Centre
2016— 2017	Main sponsors: Kemira Oyj Neste Oil Oyj In addition, operations were sponsored by: BASF Oy Borealis Polymers Oy Chemical Industry Federation of Finland Oy AGA Ab UPM-Kymmene Oyj	IS-Vet Oy Laskentaväline Oy Metrohm Nordic Oy Miliot Science Finland's 3M Oy Thermo Fisher Scientific Oy VWR International Oy	City of Helsinki Finnish Chemical Magazine MAOL Finnish National Agency for Education Finnish Chemical Society, The Unit of Chemistry Education Finnish Bioindustries FIB Kemma Centre for Chemistry Education the Faculty of Pharmacy, University of Helsinki National LUMA Centre
2017— 2018	Main sponsor: Neste Oyj In addition, operations were sponsored by:	Is-Vet Oy Laskentaväline Oy Metrohm Nordic Oy Finland's 3M Oy	City of Helsinki Finnish Chemical Magazine

	BASF Oy Borealis Polymers Oy Chemical Industry Federation of Finland Kemira Oyj Oy AGA Ab UPM-Kymmene Oyj	Thermo Fisher Scientific Oy VWR International Oy	
2018— 2019	Main sponsor: Neste Oyj In addition, operations are sponsored by: BASF Oy Borealis Polymers Oy Chemical Industry Federation of Finland Kemira Oyj Oy AGA Ab UPM-Kymmene Oyj	Is-Vet Oy Laskentaväline Oy Metrohm Nordic Oy Finland's 3M Oy Thermo Fisher Scientific Oy VWR International Oy	City of Helsinki Finnish Chemical Magazine MAOL Finnish National Agency for Education Finnish Chemical Society, The Unit of Chemistry Education Finnish Bioindustries FIB National LUMA Centre